pages = 129 x 2 = 258

ATARI 400/800 OPERATING SYSTEM USER'S MANUAL
August 15, 1980

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15-Aug-80

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1. Introduction

1.1 Purpose of manual

This manual provides a description of the Resident Operating System for the Atari 400/800 computers, for use by persons concerned with the internal behavior of the systems. This manual discusses: 1) the functions provided by the system and how to use them, 2) the organization of the various subsystems, 3) the characteristics of the Atari peripheral devices which may be attached, 4) standard techniques for going beyond the basic O.S. capabilities, and 5) the general nature of the hardware involved.

This manual assumes that the reader is already familiar with programming concepts and jargon, assembly language programming in general and with the Synertek 6502 in particular, and has some degree of familiarity with digital hardware. The primary intent is to provide an experienced programmer with sufficient information so that he or she can effectively utilize the resources provided by the O.S. without having to resort to O.S. listings or trial and error techniques. A secondary goal is to provide supporting information for those individuals who do have to work with the O.S. listings.

This manual does not attempt to describe the hardware being used to provide the O.S. capabilites in any comprehensive fashion. Therefore, the person wanting to go beyond the capabilities described herein are advised to examine the CANDY/COLLEEN HARDWARE MANUAL. This statement applies most widely to persons involved in the design of game cartridges, where display requirements, system timing and/or memory requirements preclude usage of the O.S. for one or more functions.

1.2 General description of the Atari 400/800

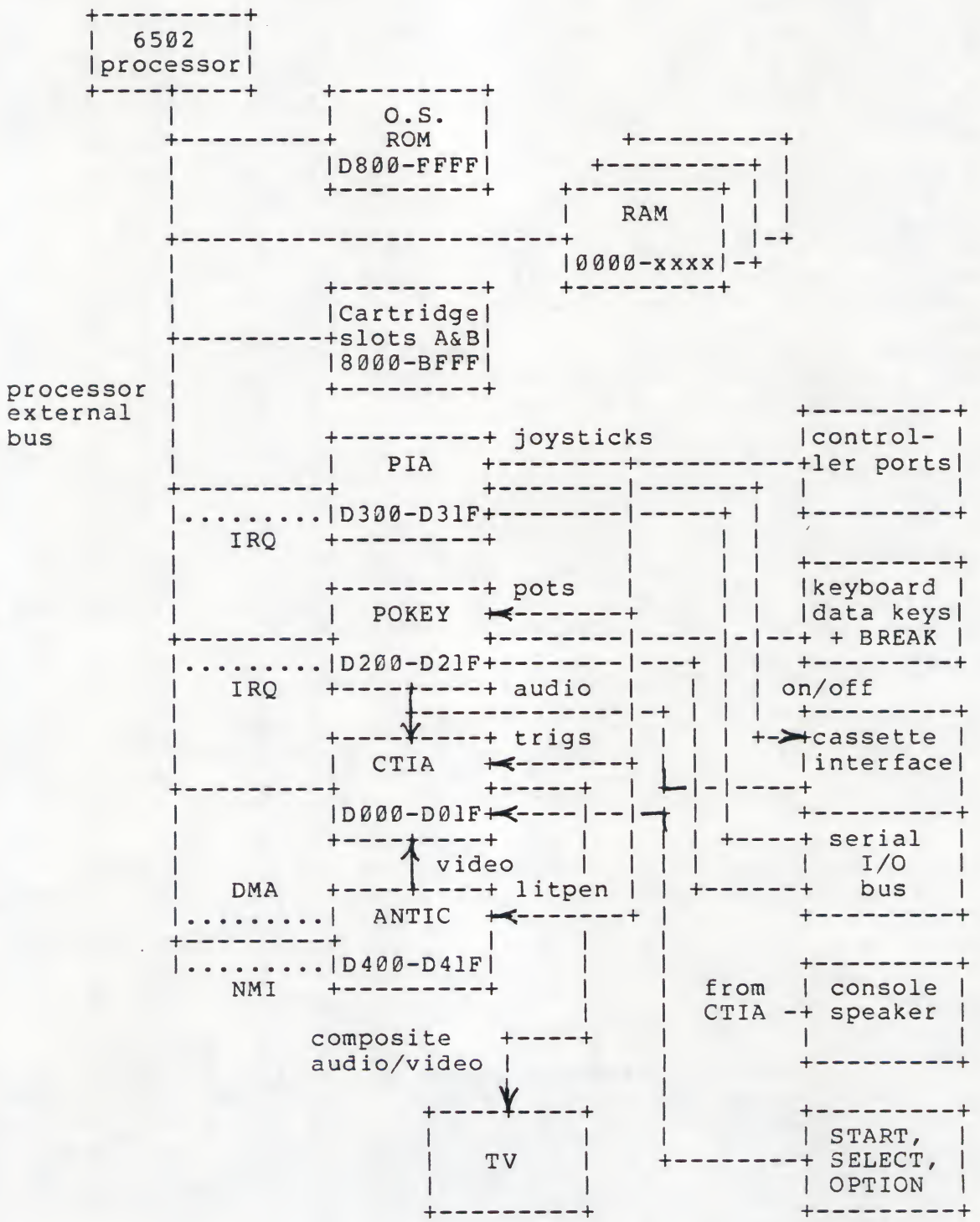
The Atari 400 and 800 are both personal computer systems. The two models are virtually identical from the standpoint of the operating system; in fact, the O.S. is identical in both models. The primary differences between the 400 and 800 are:

* Physical packaging.
* The 400 has one cartridge slot, the 800 has two slots.
* The 400 has 16K RAM maximum, the 800 has 48K RAM maximum.

The hardware contains circuitry to: produce both character and point graphics for B/W or color television, produce four independent audio channels (frequency controlled) which use the TV sound system, provide one bi-level audio output in the base unit, interface to up to 4 joysticks/8 paddle controllers/4 driving controllers/1 lightpen, interface to a serial I/O bus for expansion, and has a built in keyboard. A simplified block diagram of the hardware is shown on the next page.

Atari 400/800 Block Diagram

The diagram below shows a simplified block diagram of the Atari 400/800 hardware; see the CANDY/COLLEEN HARDWARE MANUAL for supporting documentation.



1.3 Notations used in this manual

Several special notations are used throughout this manual in order to concisely present certain types of information such as hexadecimal numbers, memory addresses and data syntax. These notations are explained in the paragraphs that follow.

MEMORY ADDRESSES

All references to computer memory (and mapped I/O) locations will be in hexadecimal notation; sometimes the addresses will be contained in square brackets, such as '[D20F]', and sometimes not, such as 'D20F'.

HEXADECIMAL NUMBERS

All two digit numbers preceded by a dollar sign ('$') are to be read as hexadecimal numbers. Where not so prefixed, or specified otherwise by supporting text, a number that is not a memory address is expressed in decimal .

KILOBYTES OF MEMORY

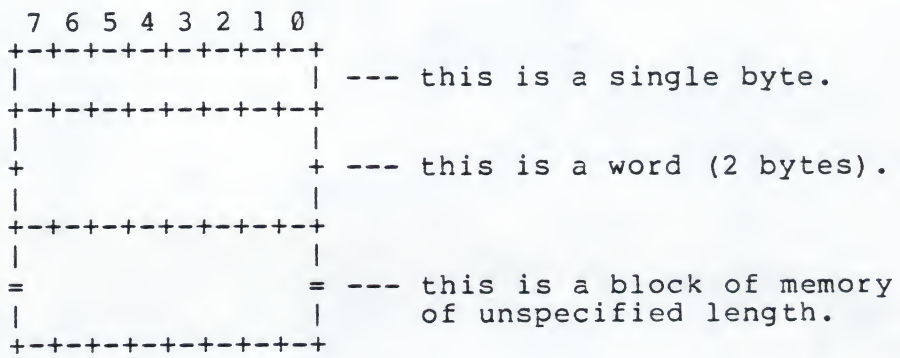
Memory sizes are frequently expressed in units of kilobytes, such as 32K, where a kilobyte is 1024 bytes of memory.

PASCAL AS AN ALGORITHM SPECIFICATION LANGUAGE

In the few places where an algorithm is specified in detail, the Pascal language (procedure block only) is used as the specification language. Pascal syntax is similar to that of any number of other block structured languages, and the user should have no difficulty following the code presented.

MEMORY LAYOUTS

Whenever pictures of bytes or tables are presented, figures similar to the one shown below are used:



Where bit-7 is the most significant bit (msb) of the byte, and bit-0 is the least significant bit (lsb).

In table figures, memory addresses always increase toward the bottom of the figure.

BACKUS-NAUR FORM (BNF)

A modified version of BNF is used to express some syntactic forms, where the following meta-linguistic symbols are used:

::=	is the substitution (assignment) operator.
< >	bracket a metasyntactic variable.
|	separates alternative substitutions.
[ ]	bracket an optional construct.

anything else is a syntactic literal constant, which stands for itself.

For example:

```
<device specification> ::= <device name>[<device number>]:
<device name> ::= C|D|E|K|P|R|S
<device number> ::= 1|2|3|4
```

The above statements specify that something called a "device specification" consists of a mandatory "device name" followed by an optional "device number" followed by the character ':'. The "device name", in turn, must be one and only one of the characters shown as alternatives; while the "device number" (if it is present) must be a digit 1 through 4.

O.S. EQUATE FILE NAMES

Operating system ROM and RAM vector names, RAM database variable names and hardware register names are all referred to herein by the names assigned in the O.S. program equate list; in most cases, when one of these names is used, the memory address is provided also, such as 'BOOTAD [0242]'.

2. Operating System functional organization

This section describes the various subsystems of the resident O.S. in general terms.

2.1 I/O subsystem

The I/O subsystem provides a high-level interface between the programs and the hardware. Most functions are device independent, such as the reading and writing of character data; yet provisions have been made for device dependent functions as well. All peripheral devices capable of dealing with character data have symbolic individual symbolic names (such as K,D,P, etc.) and may be accessed using a Central I/O (CIO) routine.

Controllers such as joysticks, paddle controllers and lightpen, which do not deal with character data, are accessed via a RAM data base which is periodically updated to show the states of these devices.

2.2 Interrupt processing

All hardware interrupts are handled in a common and consistent manner by the Interrupt subsystem. By default, all interrupts are fielded by the O.S., but at the discretion of the user, individual interrupts (or groups of interrupts) may be fielded by the application program.

2.3 Initialization

There are two levels of initialization provided by the system: power-up and RESET. Power-up initialization is performed each time the system power is turned on, and RESET initialization is performed each time the RESET key is pressed.

2.3.1 Power-up

Whenever system power is turned on, the O.S. examines and notes the configuration of the unit; the following items are among those things performed at power-up:

Determine the highest RAM address.
Clear all of RAM to zeroes.
Establish all RAM interrupt vectors.
Format the Device Table.
Initialize the cartridge(s).
Setup the screen for 24 x 40 text mode.
Boot the cassette if directed.
Check cartridge slot(s) for disk boot instructions.
Boot the disk if directed to do so and a disk is attached.
Transfer control to the cartridge, disk booted program, cassette booted program, or blackboard program.

2.3.2 RESET

Whenever the RESET key is pressed, the O.S. performs some, but not all, of the functions performed at power-up; the following items are among those things performed as a result of pressing the RESET key:

Clear the O.S. portion of RAM.
Re-establish all RAM interrupt vectors.
Format the Device Table.
Initialize the cartridge(s).
Setup the screen for 24 x 40 text mode.
Transfer control to the cartridge, disk booted program, cassette booted program, or blackboard program.

2.4 Floating point arithmetic package

Contained within the O.S. ROM is a floating point package which is not used by the other parts of the O.S. itself, but is available to non-resident programs such as BASIC, Calculator, Pascal, etc. The floating point numbers are stored as 10 BCD digits of mantissa plus a 1 byte exponent. The following routines are among those found in the package:

ASCII to F.P and F.P. to ASCII conversion.
Integer to F.P. and F.P. to integer conversion.
F.P. add, subtract, multiply and divide.
F.P. log, exp and polynomial evaluation.
F.P. number clear, load, store and move.

3. Configurations

The Models 400/800 support a wide variety of configurations, each with a unique operating environment: cartridge(s) may or may not be inserted, memory may be optionally added in 8K or 16K increments, and many different peripheral devices may be attached to the serial I/O bus. The O.S. accounts for all of these variables without requiring a change in the resident O.S. itself. As explained in the preceding section, the machine configuration is checked when power is first turned on and then is not checked again. A general discussion of some of the valid configurations is given in the remainder of this section.

3.1 Program environments

The O.S. allows one of four program types to be in control at any point in time: the O.S. blackboard ("memo pad") program, a cartridge resident program, a disk booted program or a cassette booted program. Which one of these is in control is based upon information in the cartridge(s), whether or not a disk is attached and operator keyboard inputs; the exact algorithms are discussed in detail in section 7.

3.1.1 Blackboard mode

When in blackboard mode, the screen is estblished as a 24 x 80 text screen. Anything entered from the keyboard goes to the screen without being examined; although all of the screen editing functions are supported. Blackboard mode is the lowest priority environment; one only goes there if there is no other reasonable environment for the O.S. to enter or if the operator requests a higher priority environment to enter the blackboard mode (e.g. BYE in BASIC). Blackboard mode may be exited by pressing the RESET key, if it was entered from a higher priority environment.

3.1.2 Cartridge

When a cartridge is inserted, it normally provides the main control after initialization is complete; for example: BASIC, SUPERBREAKOUT, BASKETBALL, CHESS, etc. all interface directly with the user in some way. Although it is possible for a cartridge to provide a supporting function for some other program environment, this has not been done to date. In some cartridges, particularly keyboard oriented ones, it possible to change environments by entering special commands such as "BYE" to go to blackboard mode or "DOS" to enter the Disk Utility. In many other cartridges, particulary games, it is not possible to change environments. Note that because of a hardware interlock it is impossible to remove or insert a cartridge with the power on; this means (among other things) that every cartridge change will completely re-initialize the entire system.

3.1.3 Disk boot

When the system powers up with a disk attached with disk bootable software, the disk may or may not be booted, depending upon conditions explained in section 7. The rest of this paragraph assumes that a disk boot did occur.

The disk booted software may take control as the Disk Utility does under certain conditions, or may provide a supporting function as the File Management System does; this environment is so flexible that it is difficult to generalize on its capabilities and restrictions. The only machine requirement (other than the disk drive) is that sufficient RAM be installed to support the program being booted.

3.1.4 Cassette boot

Everything that was said about the disk boot environment is also true about the cassette boot environment, although the cassette is limited as an I/O device due to its slowness, sequential access and single file at a time nature. Those limitations probably limit cassette booted software to "cartridge type" programs, 100% RAM resident and not involving random access nor much I/O involving permanent storage. Note that the cassette boot facility has no relation to the use of cassettes to store high level language programs (e.g. programs written in BASIC) nor to the use of cassettes to store data.

3.2 RAM expansion

Although RAM may be expanded non-contiguously by the user, the O.S. will only recognize RAM that is contiguous starting from location 0. Directions for installing the RAM modules are provided with the purchased modules. RAM may be added until it totals 48K; after 32K, additional RAM overlays first the right cartridge addresses (32K to 40K) and then the left cartridge addresses (40K to 48K). Note that in cases of conflict, the inserted cartridge has higher priority. See section 4. for a detailed discussion of system memory.

As a result of power-up the O.S. will generate two pointers that define the lowest available RAM location and the highest available RAM location. The O.S. and disk/cassette booted software will determine the location of the lowest available RAM, while the number of RAM modules and the current screen mode will determine the highest available RAM.

3.3 Peripheral devices

Peripheral devices of several types may be added to the system using standard cables to either the serial bus or the connectors at the front of the base unit. The most common types deal with either transmission of bytes of data (usually serial bus) or transmission of sense information (usually game controllers).

3.3.1 Game controllers

The standard game controllers (pots, joysticks, driving controllers and the light pen) are sensed periodically (50 or 60 times per second) by the O.S. and the values read are stored in RAM. These controllers may be plugged in, pulled out, and re-arranged at will by the user without affecting system operation; the system will always try to read all of these controllers. Other controllers, such as the keyboard controller, are not read by the O.S. and special instructions as described in section 11 are required to read them.

3.3.2 Cassette

The cassette is a special peripheral in that it uses the serial bus to send and receive data, but does not conform to the protocol of the other peripherals that use the serial bus. The cassette must also be the last device on the serial bus because it does not have a serial bus extender connector as the other peripherals do. The lack of a bus extender assures that there is never more than one cassette drive connected to any system. The system cannot sense the absence or presence of the cassette drive, so it may be connected and disconnected at will.

3.3.3 Serial bus devices

By serial bus devices we mean those that conform to the serial I/O bus protocol as defined in section 9.4; this does not include the cassette drive. Each serial bus device has two identical connectors: one a serial bus input, the other a serial bus extender. Either connector may be used for either purpose, and peripherals may be "daisy chained" simply be cabling them together in a sequential fashion. There are usually no restrictions on the cabling order, as each device has a unique identifier; where there are restrictions, they will be mentioned in section 5.5. Whether or not a peripheral must be "on the bus" at power-up is discussed for each peripheral in section 5.5.

4. System memory utilization

Memory in the system is decoded in the full 64K range of the 6502 microcomputer and there are no provisions for additional mapping to extend memory. Memory is divided into four basic regions (with some overlap possible): RAM, cartridge area, I/O region and the resident O.S. ROM. The regions and their address boundaries are listed below (all addresses are in hexadecimal):

```
0000-1FFF = RAM (minimum required for operation)
2000-7FFF = RAM expansion area
8000-9FFF = Cartridge B or RAM
A000-BFFF = Cartridge A or RAM
C000-CFFF = unused
D000-D7FF = Hardware I/O decodes
D800-DFFF = Floating point package (O.S.)
E000=EFFF = Resident Operating System ROM
```

The remainder of this section will break these regions into even smaller functional divisions and provide detailed explanations of their usage.

4.1 RAM region

The RAM region is shared between the O.S and the program in control and can be further subdivided into the following sub-regions for discussion purposes:

```
Page 0 = 6502 direct address mode region.
Page 1 = 6502 stack region.
Pages 2-4 = O.S. database & user workspace.
Pages 5-6 = User program workspace.
Pages 7-XX = Bootable software area/free RAM.
Pages XX-top of RAM = screen display list and data.
```

The paragraphs that follow indicate the O.S. usage and recommended user program usage of these RAM sub-regions.

4.1.1 Page 0

Because of the architecture of the 6502 microcomputer instruction set and addressing modes, page 0 has special significance; references to addresses in that page (0000 to 00FF) are faster, require fewer instruction bytes and provide the only mechanism for hardware indirect addressing. Therefore page 0 is a resource that has to be utilized sparingly so that all possible users may have portion of it. The O.S. permanently takes the lower half of page 0 (0000 to 007F) and this portion may never be used by any outer environment unless the O.S. is completely disabled and all interrupts to the O.S. are eliminated.

The upper half of page 0 (0080 to 00FF) is available to outer envirnments with the following restriction: the floating point package, if used, requires 00D4 through 00FF.

4.1.2 Page 1

Page 1 is the 6502 hardware stack region; JSR instructions, PSH instructions and interrupts all cause data bytes to be written

to page 1 and conversely RTS, PUL and RTI instructions all cause data bytes to be read from page 1. The 256 byte stack is adequate for normal subroutine calls plus interrupt process nesting, so no restrictions have been made on page 1 usage. It is obvious that a stack of this size is totally inadequate for deeply recursive processes or for nested processes with large local environments to be saved. So, for sophisticated applications, software maintained stacks must be implemented.

The 6502 stack pointer is initialized at power-up or RESET to point to location 01FF, the stack then pushes downward toward 0100.

4.1.3 O.S. database

Locations 0200 through 047F are allocated by the O.S. for working variables, tables and data buffers. Portions of this region may be used only after it is determined that non-conflict with the O.S. is guaranteed; e.g. the printer and cassette buffers could be used if I/O operations to these devices are impossible within the controlling environment. The amount of work involved in determining non-conflict seems to be completely out of line with the benefits to be gained (except for a few trivial cases) and it is recommended that pages 2 through 4 not be used except by the O.S.

4.1.4 User workspace

Locations 0480 through 06FF are dedicated for outer environment use except when the floating point package is used, in which case it uses locations 057E through 05FF.

4.1.5 Boot region

Page 7 is the start of the "boot region". When software is booted from either the disk or the cassette, it starts at the lowest free memory address (which is 0700) and procedes upward. The top of this region defines the start of the "free memory" region. When the boot process is complete, a pointer in the data base contains the address of the next available location above the software just booted. When no software has been booted, this pointer contains the value 0700.

4.1.6 Screen display list and data

When the O.S. is handling the screen display, the display list which defines the screen characteristics and the current data which is contained on the screen are placed at the high address end of RAM. The bottom of this region defines the end of the "free memory" region and its location is a function of the screen mode currently in effect. A pointer in the data base contains the address of the last available location below the screen region.

4.1.7 Free memory region

The free memory region is all that RAM between the end of the boot region and the start of the screen region. The outer level application is responsible for managing the free memory region. See section 4.6 for more details.

4.2 Cartridges A and B

There are two 8K regions reserved for plug-in cartridges. Cartridge B, which is the "right" cartridge slot found only in the model 800, has been allocated memory addresses 8000 through 9FFF; while cartridge A, which is the "left" cartridge slot in the model 800, and is the only slot in the model 400, has been allocated memory addresses A000 through BFFF. If a RAM module is plugged into the last slot such as to overlay any of these addresses, the RAM takes precedence as long as a cartridge is not inserted; however, if a cartridge is inserted, it will disable the entire conflicting RAM module in the last slot.

4.3 Mapped I/O

The 6502 performs input/output operations by addressing the external support chips as memory; some chip registers are read/write while others are read only or write only (the CANDY/COLLEEN HARDWARE MANUAL gives descriptions of all of the external registers). While the entire address space from D000 to D7FF has been allocated for I/O decoding, only the following sub-regions are used:

D000-D01F = CTIA
D200-D21F = POKEY
D300-D31F = PIA
D400-D41F = ANTIC

4.4 Resident O.S. and floating point package ROM

The region from D800 through FFFF always contains the O.S. and the floating point package. To allow for the possibility that another, but functionally compatible, O.S. may be generated in the future, care should be taken to avoid using any entry points that are not guaranteed not to move. The O.S. contains many vectored entry points at the end of the ROM and in RAM which will not move. The floating point package is not vectored, but all documented entry points will be fixed (this means do not use undocumented routines found by scanning the listing!). A list of the fixed ROM vectors and entry points may be found in Appendix J.

4.5 Central data base description

Discussion of organization of this section.

There are a large number of variables in the O.S. data base, most of which have some relevance to the user, either for control or debug purposes. This section provides detailed information for those variables which can be altered by the user in meaningful ways and to provides at least a narrative description of the remaining variables. One major problem, when dealing with this many variables, is how to present the information so that it is accessible to the user in the different contexts in which he works. This manual attempts to solve that problem by providing a multiple access scheme, in which several lookup tables are provided, all of which reference a common set of narrative that is itself ordered by function.

In order to provide a means of referencing the variable descriptions, while avoiding confusion with the document paragraph numbering scheme, the variable descriptions are each provided with a label consisting of a single letter followed by a number (e.g. A4, B13, etc.). A different letter is assigned for each major functional area being described, and the numbers are assigned sequentially within each functional area. This label just described will be referred to as a VID (variable identifier) throughout the remainder of this document.

The database lookup tables provided are:

1. Functional grouping -- index to the function narrative and descriptions of variables, giving VID and variable name.

2. Alphabetic list of names -- giving VID of description.

3. Address ordered list -- giving VID of description.

Item 1, the functional grouping index, follows immediately on the next page. Items 2 and 3, the name and address ordered lists, fall at the end of this section after the variable descriptions.

FUNCTIONAL INDEX TO DATABASE VARIABLE DESCRIPTIONS

A. Memory configuration
- A1 MEMLO
- A2 MEMTOP
- A3 APPMHI
- A4 RAMTOP*
- A5 RAMSIZ

B. Text/graphics screen

Cursor control
- B1 CRSINH
- B2 ROWCRS,COLCRS
- B3 OLDROW,CLDCOL
- B4 TXTROW,TXTCOL

Screen margins
- B5 LMARGN
- B6 RMARGN

Color control
- B7 PCOLR0 - PCOLR3
- B8 COLOR0 - COLOR4

Text scrolling
- B9 SCRFLG*

Attract mode
- B10 ATRACT
- B11 COLRSH*
- B12 DRKMSK*

Tabbing
- B13 TABMAP

Logical text lines
- B14 LOGMAP*
- B15 LOGCOL*

Split screen
- B16 BOTSCR*

FILL/DRAW function
- B17 FILDAT
- B18 FILFLG*
- B19 NEWROW*,NEWCOL*
- B20 HOLD4*
- B21 ROWINC*,COLINC*
- B22 DELTAR*,DELTAC*
- B23 COUNTR*
- B24 ROWAC*,COLAC*
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- B26 ESCFLG*

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- B27 DSPFLG

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- B31 HOLD2*
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- B33 TMPCHR*
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B35 DINDEX*
B36 SAVMSC*
B37 OLDCHR*
B38 OLDADR*
B39 ADRESS*
B40 MLTTMP/CPNTMP/TOADR*
B41 SAVADR/FRMADR*
B42 BUFCNT*
B43 BUFSTR*
B44 SWPFLG*
B45 INSDAT*
B46 TMPROW*,TMPCOL*
B47 TMPLBT*
B48 SUBTMP*
B49 TINDEX*
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D3 TIMER1*,TIMER2*
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D13 FTYPE*
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```
      E7 HOLDCH*
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      G2 ICHID
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      G5 ICSTA
      G6 ICBAL,ICBAH
      G7 ICPTL,ICPTH
      G8 ICBLL,ICBLH
      G9 ICAX1,ICAX2
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      G11 DVSTAT
    Device Table
      G12 HATABS
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    G13 ZIOCB (IOCBAS)
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      G20 ICBLLZ,ICBLHZ
      G21 ICAX1Z,ICAX2Z
      G22 ICSPRZ (ICIDNO,CIOCHR)
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      H3 DUNIT
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```

H10 SOUNDR
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H11 CRETRY*
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H13 CHKSUM*
H14 CHKSNT*
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H21 BUFRFL*
H22 RECVDN*
H23 TEMP*
H24 XMTDON*
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H25 TIMFLG*
H26 CDTMV1*
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H29 TSTAT*
H30 ERRFLG*
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J3 PADDL0 - PADDL7
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J7 STICK0
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M2 FRE*
M3 FR1
M4 FR2*
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M6 EEXP*
M7 NSIGN*
M8 ESIGN*
M9 FCHRFLG*
M10 DIGRT*
M11 CIX
M12 INBUFF
M13 ZTEMP1*
M14 ZTEMP4*
M15 ZTEMP3*
M16 FLPTR
M17 FPTR2*
M18 LBPR1*
M19 LBPR2*
M20 LBUFF
M21 PLYARG*
M22 FPSCR/FSCR*
M23 FPSCR1/FSCR1*
M24 DEGFLG/RADFLG*

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N1 RAMLO*,TRAMSZ*
N2 TSTDAT*
Disk/cassette boot
N3 DOSINI
N4 CKEY*
N5 CASSBT*
N6 CASINI
N7 BOOT?*
N8 DFLAGS*
N9 DBSECT*
N10 BOOTAD*
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N12 DOSVEC
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P1 CRITIC
P2 POKMSK
System timers
Real-time clock
P3 RTCLOK
System timer 1
P4 CDTMV1
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P6 CDTMV2
P7 CDTMA2
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P8 CDTMV3,CDTMV4,CDTMV5
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RAM interrupt vectors
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P10 VDSLST
P11 VVBLKI
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IRQ interrupt vectors
P13 VIMIRQ
P14 VPRCED
P15 VINTER
P16 VBREAK
P17 VKEYBD
P18 VSERIN
P19 VSEROR
P20 VSEROC
P21 VTIMR1,VTIMR2,VTIMR4
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P22 SDMCTL*
P23 SDLSTL*,SDLSTH*
P24 GPRIOR*
P25 CHACT*
P26 CHBAS*
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Internal working variable
P28 INTEMP*

R. User areas
R1 (unlabeled)
R2 USAREA

S. Unused (spare) bytes
S1 HOLD5
S2 CSTAT
S3 DUNUSE
S4 TEMP2
S5 TMPX1
S6 DSKFMS
S7-S15 (unlabeled)

O.S. DATABASE VARIABLE FUNCTIONAL DESCRIPTIONS

This section contains descriptions of many of the data base variables; descriptions are included for all of the user accessible variables and for some of the "internal" variables as well. Those variables which are not considered to be normally of interest to any user are flagged with an asterisk ('*') after their names; the other variables may be of interest to one or more of the following classes of users:

End user.
Game developer.
Application programmer.
System utility writer.
Language processor developer.
Device handler writer.

Each variable is specified by its system equate file name followed by its address (in hex) and the number of bytes reserved in the data base (in decimal), in the following form:

<name> [<address>,<size>]

For example:

MEMLO [02E7,2]

A. MEMORY CONFIGURATION

See section 4.6 for a general discussion of memory dynamics and section 7 for details of system initialization.

A1 MEMLO [02E7,2] -- User free memory low address

MEMLO contains the address of the first location in the free memory region. The value is established by the O.S. during power-up and RESET initialization and is never altered by the O.S. thereafter.

A2 MEMTOP [02E5,2] -- User free memory high address

MEMTOP contains the address of the first non-useable memory location above the free memory region. The value is established by the O.S. during power-up and RESET initialization; and then is re-established whenever the display is OPENed.

A3 APPMHI [000E,2] -- User free memory screen lower limit

APPMHI is a user controlled variable which contains the address within the free memory region below which the Display handler may not go in setting up a display screen. This variable is initialized to zero by the O.S. at power-up.

A4 RAMTOP* [006A,1] -- Display handler top of RAM address (msb)

RAMTOP permanently retains the RAM top address that was contained in TRAMSZ (as described in N1) for the Display

handler's use. The value is setup as part of handler initialization; it is not clear why this variable is required, since the same value is in RAMSIZ.

A5 RAMSIZ [02E4,1] -- Top of RAM address (msb only)

RAMSIZ permanently retains the RAM top address that was contained in TRAMSZ (as described in N1).

B. TEXT/GRAPHICS SCREEN

See sections 5.3.2 and 5.3.3 for a discussion of the text and graphics screens and their handlers.

Cursor control

For the text screen and split screen text window there is a visible cursor on the screen which shows the position of the next input or output operation. The cursor is represented by inverting the video of the character upon which it resides; but the cursor may be made invisible, at the user's option. The graphics screen always has an invisible cursor.

The cursor position is sensed by examining data base variables and may be moved by altering those same variables; in addition, when using the Screen Editor, there are cursor movement control codes which may be sent as data (as explained in section 5.3.3).

B1 CRSINH [02F0,1] -- Cursor display inhibit flag

When CRSINH is zero, all outputs to the text screen will be followed by a visible cursor (inverted character); and when CRSINH is non-zero, no visible cursor will be generated.

CRSINH is set to zero by power-up, RESET, BREAK or an OPEN command to the Display handler or Screen Editor.

Note that altering CRSINH does not cause the visible cursor to change states until the next output to the screen; if an immediate change to the cursor state is desired, without altering the screen data, follow the CRSINH change with the output of CURSOR UP, CURSOR DOWN or some other innocuous sequence.

B2 ROWCRS [0054,1] & COLCRS [0055,2] -- Current cursor position

ROWCRS and COLCRS define the cursor location (row and column, respectively) for the next data element to be read from or written to the main screen segment. When in split screen mode, the variables TXTROW and TXTCOL define the cursor for the text window at the bottom of the screen as explained in B4 below.

The row and column numbering start with the value zero, and increase monotonically to the number of rows or columns minus one; with the upper left corner of the screen being the origin (0,0).

ROWCRS is a single byte variable with a maximum allowable value

of 191 (screen modes 8-11); COLCRS is a two byte variable with a maximum allowable value of 319 (screen mode 8).

B3 OLDROW [005A,1] & OLDCOL [005B,2] -- Prior cursor position

OLDROW and OLDCOL are updated from ROWCRS and COLCRS before every operation. The variables are used only for the DRAW and FILL operations.

B4 TXTROW [0290,1] & TXTCOL [0291,2] -- Split screen text cursor position

TXTROW and TXTCOL define the cursor location (row and column, respectively) for the next data element to be read from or written to the split screen text window.

The row and column numbering start with the value zero, and increase monotonically to 3 and 39, respectively; with the upper left corner of the split screen text window being the origin (0,0).

Screen margins

The text screen and split screen text window have user alterable left and right margins which define the normal domain of the text cursor.

B5 LMARGN [0052,1] -- Text column left margin

LMARGN contains the column number (0-39) of the text screen left margin; the text cursor will remain on or to the right of the left margin as a result of all operations, unless the cursor column variable is directly updated by the user (see B2 and B4 above). The default value for LMARGN is 2 and is established upon power-up or RESET.

B6 RMARGN [0053,1] -- Text column right margin

RMARGN contains the column number (0-39) of the text screen right margin; the text cursor will remain on or to the left of the right margin as a result of all operations, unless the cursor column variable is directly updated by the user (see B2 and B4 above). The default value for RMARGN is 39 and is established upon power-up or RESET.

Color control

As part of the stage 2 VBLANK process (see section 6.3.2), the values of nine data base variables are stored in corresponding hardware color control registers. The color registers are divided into two groups: 1) the player/missile colors and 2) the playfield colors. The playfield color registers are utilized by the different screen modes as shown in Appendix H; the player/missile color registers have no use within the standard C.S.

B7 PCOLR0 - PCOLR3 [02C0,4] -- Player/missile colors

Each color variable is stored in the corresponding hardware register as shown below:

PCOLR0 [02C0]	COLPM0 [D012]
PCOLR1 [02C1]	COLPM1 [D013]
PCOLR2 [02C2]	COLPM2 [D014]
PCOLR3 [02C3]	COLPM3 [D015]

Each color variable has the format shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
| color | lum |x|
+-+-+-+-+-+-+-+-+
```

See Appendix H for information regarding the color and luminance field values.

B8 COLOR0 - COLOR4 [02C5,5] -- Playfield colors

Each color variable is stored in the corresponding hardware register as shown below:

COLOR0 [02C4]	COLPF0 [D016]
COLOR1 [02C5]	COLPF1 [D017]
COLOR2 [02C6]	COLPF2 [D018]
COLOR3 [02C7]	COLPF3 [D019]
COLOR4 [02C8]	COLBK [D01A]

Each color variable has the format shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
| color | lum |x|
+-+-+-+-+-+-+-+-+
```

See Appendix H for information regarding the color and luminance field values.

Text scrolling

The text screen or split screen text window "scrolls" upward whenever one of the two conditions shown below occurs:

A text line at the bottom row of the screen extends past the right margin.

A text line at the bottom row of the screen is terminated by an EOL.

Scrolling has the effect of removing the entire logical line that starts at the top of the screen and then moving all subsequent lines upward to fill in the void. The cursor will also move upward if the logical line deleted exceeds one physical line.

B9 SCRFLG* [02BB,1] -- Scroll flag

SCRFLG is a working variable that counts the number of physical lines minus one that were deleted from the top of the screen; since a logical line ranges in size from 1 to 3, SCRFLG ranges from 0 to 2.

Attract mode

As part of the stage 2 VBLANK process, the color registers from the data base are sent to the corresponding hardware color registers; before they are sent, they undergo the following transformation:

hardware register = database variable XOR COLRSH AND DRKMSK

Normally COLRSH = $00 and DRKMSK = $FE, thus making the above calculation a null operation; however, once attract mode becomes active, COLRSH = the content of RTCLOK+1 and DRKMSK = $F6, which has the effect of modifying all of the colors and keeping their luminance always below the 50% level.

Since RTCLOK+1 is incremented every 256/60ths of a second and since the least significant bit of COLRSH is of no consequence, a color/lum change will be effected every 8.53 seconds (512/60).

B10 ATRACT [004D,1] -- Attract mode timer and flag

ATRACT is the timer (and flag) which controls the initiation and termination of attract mode. Whenever a keyboard key is pressed, the keyboard IRQ service routine sets ATRACT to zero, thus terminating attract mode; the BREAK key logic behaves accordingly. As part of the stage 1 VBLANK process, ATRACT is incremented every 4.3 seconds; if the value exceeds 127 (after 9.1 minutes without keyboard activity), the value of ATRACT will then be set to $FE and will retain that value until attract mode is terminated.

Since the attract mode is prevented and terminated by the O.S. based only upon keyboard activity, some users may want to reset ATRACT based upon Atari controller event detection, user controlled Serial I/O bus activity or any other signs of life.

B11 COLRSH* [004F,1] -- Color shift mask

COLRSH has the value $00 when attract mode is inactive, thus effecting no change to the screen colors; when attract mode is active, COLRSH contains the current value of the timer variable middle digit (RTCLOK+1).

B12 DRKMSK* [004E,1] -- Dark (luminance) mask

DRKMSK has the value $FE when attract mode is inactive which does not alter the luminance; and has the value $F6 when attract mode is active which forces the most significant bit of the luminance field to zero, thus guaranteeing that the luminance will never exceed 50%.

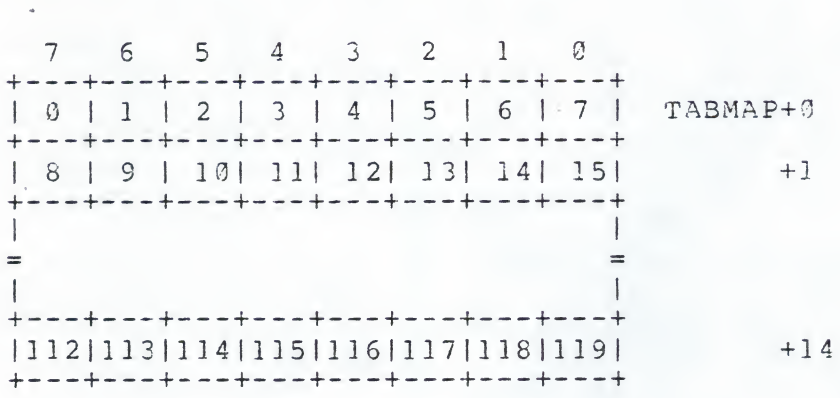
Tabbing

See section 5.3.3 for a discussion of the use of tabs in conjunction with the Screen Editor.

B13 TABMAP [02A3,15] -- Tab stop setting map

The tab settings are retained in a fifteen byte (120 bit) map, where a bit value of one indicates a tab setting; the diagram

below shows the mapping of the individual bits to tab positions.



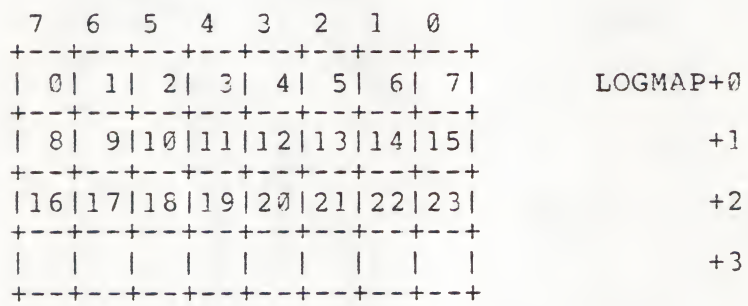
Whenever the Display handler or Screen Editor is OPENed, this map is initialized to contain the value of $01 in every byte, thus providing the default tab stops at 7, 15, 22, etc.

Logical text lines

The text screen is invisibly divided into logical lines of text, each comprising from one to three physical lines of text. The screen is initialized to 24 logical lines of one physical line each; but data entry and/or data insertion may increase the size of a logical line to two or three physical lines.

B14 LOGMAP* [02B2,4] -- Logical line starting row map

The beginning physical line number for each logical line on the screen is retained in a four byte (32 bit) map, where a bit value of one indicates the start of a logical line; the diagram below shows the mapping of the individual bits to physical line (row) numbers.



The map bits are all set to one whenever the text screen is OPENed or cleared. From that point, the map is updated as logical lines are entered, edited and deleted from the screen.

B15 LOGCOL* [0063,1] -- Cursor/logical line column number

LOGCOL contains the logical line column number for the current cursor position; note that a logical line may comprise up to three physical lines. This variable is for the internal use of the Display handler.

Split screen

The Display handler and Screen Editor together support the operation of a split screen mode (see sections 5.3.2 and 5.3.3) in which the main portion of the screen is in one of the graphics modes and is controlled by the Display handler, and there is a four physical line text window at the bottom of the screen which is controlled by the Screen Editor.

B16 BOTSCR* [02BF,1] -- Text screen lines count

BOTSCR contains the number of lines of text for the current screen: 24 for mode 0 or 4 for a split screen mode. The handler also uses this variable as an indication of the split screen status; tests are made for the specific values 4 and 24.

DRAW/FILL function

The DRAW function line drawing algorithm is shown below translated to the Pascal language from assembly language.

```
NEWROW := ROWCRS; NEWCOL := COLCRS;

DELTAR := ABS (NEWROW-OLDROW);
ROWINC := SIGN (NEWROW-OLDROW); { +1 or -1 }

DELTAC := ABS (NEWCOL-OLDCOL);
COLINC := SIGN (NEWCOL-OLDCOL); { +1 or -1 }

ROWAC := 0; COLAC := 0;
ROWCRS := OLDROW; COLCRS := OLDCOL;

COUNTR := MAX (DELTAC,DELTAR);
ENDPT := COUNTR;
IF COUNTR = DELTAC
   THEN ROWAC := ENDPT DIV 2
   ELSE COLAC := ENDPT DIV 2;

WHILE COUNTR > 0 DO
   BEGIN

      ROWAC := ROWAC + DELTAR;
      IF ROWAC >= ENDPT
         THEN
            BEGIN
               ROWAC := ROWAC - ENDPT;
               ROWCRS := ROWCRS + ROWINC
            END;

      COLAC := COLAC + DELTAC;
      IF COLAC >= ENDPT
         THEN
            BEGIN
               COLAC := COLAC - ENDPT;
               COLCRS := COLCRS + COLINC
            END;

      PLOT_POINT; { point defined by ROWCRS & COLCRS }

      IF FILFLG <> 0 THEN FILL_LINE;

      COUNTR := COUNTR - 1

   END;
```

The FILL function algorithm (FILL_LINE above) is described briefly in section 5.3.2.

B17 FILDAT [02FD,1] -- Fill data

FILL contains the fill region data value as part of the calling sequence for a FILL command as described in section 5.3.2.

B18 FILFLG* [02B7,1] -- Fill flag

FILFLG indicates to shared code within the Display handler whether the current operation is FILL (FILFLG <> 0) or DRAW (FILFLG = 0).

B19 NEWROW* [0060,1] & NEWCOL* [0061,2] -- Destination point

NEWROW and NEWCOL are initialized to the values in ROWCRS and COLCRS, which represent the destination endpoint of the DRAW/FILL command. This is done so that ROWCRS and COLCRS may be altered during the performance of the command.

B20 HOLD4* [02BC,1] -- Temporary storage

HOLD4 is used to save and restore the value in ATACHR during the FILL process; ATACHR is temporarily set to the value in FILDAT to accomplish the filling portion of the command.

B21 ROWINC* [0079,1] & COLINC* [007A,1] -- Row/column increment/decrement

ROWINC and COLINC are the row and column increment values; they are each set to +1 or -1 to control the basic direction of line drawing. ROWINC and COLINC represent the signs of NEWROW - ROWCRS and NEWCOL - COLCRS, respectively.

B22 DELTAR* [0076,1] & DELTAC* [0077,2] -- Delta row and delta column

DELTAR and DELTAC contain the absolute values of NEWROW - ROWCRS and NEWCOL - COLCRS, respectively; together with ROWINC and COLINC, they define the slope of the line to be drawn.

B23 COUNTR* [007E,2] -- Draw iteration count

COUNTR initially contains the larger of DELTAR and DELTAC, which is the number of iterations required to generate the desired line. COUNTR is then decremented after every point on the line is plotted, until it reaches a value of zero.

B24 ROWAC* [0070,2] & COLAC* [0072,2] -- Accumulators

ROWAC and COLAC are working accumulators which control the row and column point plotting and increment (or decrement) function.

B25 ENDPT* [0074,2] -- Line length

ENDPT contains the larger of DELTAR and DELTAC, and is used in conjunction with ROWAC/COLAC and DELTAR/DELTAC to control the plotting of line points.

Displaying control characters

Often it is useful to have ATASCII control codes (such as CLEAR, CURSOR UP, etc.) displayed in their graphic forms instead of having them perform their control function. This display capability is provided in two forms when outputting to the Screen Editor: 1) a data content form in which a special character (ESC) preceeds each control character to be displayed and 2) a mode control form.

Escape (display following control character)

Whenever an ESC character is detected by the Screen Editor, the next character following this code is displayed as data, even if it would normally be treated as a control code; the EOL code is the sole exception, it is always treated as a control

code. The sequence ESC ESC will cause the second ESC character to be displayed.

B26 ESCFLG* [02A2,1] -- Escape flag

ESCFLG is used by the Screen Editor to control the escape sequence function; the flag is set (to $80) by the detection of an ESC character ($1B) in the data stream and is reset (to 0) following the output of the next character.

Display control characters mode

When it is desired to display ATASCII control codes other than EOL in their graphics form, but not have an ESC character associated with each control code, a display mode may be established by setting a flag in the data base. This capability is used by language processors when displaying high level language statements, which may contain control codes as data elements.

B27 DSPFLG [02FE,1] -- Display control characters flag

When DSPFLG is non-zero, ATASCII control codes other than EOL are treated as data and displayed on the screen when output to the Screen Editor. When DSPFLG is zero, ATASCII control codes are processed normally.

DSPFLG is set to zero by power-up and RESET.

Bit mapped graphics

A number of temporary variables are used by the Display handler when handling data elements (pixels) going to or from the screen; of interest here are those variables which are used to control the packing and unpacking of graphics data, where a memory byte typically contains more than one data element (for example, screen mode 8 contains 8 pixels per memory byte).

B28 DMASK* [02A0,1] -- Pixel location mask

DMASK is a mask which contains zeroes for all bits which do not correspond to the specific pixel to be operated upon, and which contains ones for all bits which do correspond. DMASK may contain the values shown below in binary notation:

```
11111111  --  screen modes 1 & 2; one pixel per byte.

11110000  --  screen modes 9-11; two pixels per byte.
00001111

11000000  --  screen modes 3, 5 & 7; four pixels per byte.
00110000
00001100
00000011

10000000  --  screen modes 4, 6 & 8; eight pixels per byte.
01000000
.
00000010
00000001
```

B29 SHFAMT* [006F,1] -- Pixel justification

SHFAMT indicates the amount to shift the right justified pixel data on output, or the amount to shift the input data to right justify it on input. The value is always the same as for DMASK prior to the justification process.

Internal working variables

B30 HOLD1* [0051,1] -- Temporary storage

B31 HOLD2* [029F,1] -- Temporary storage

B32 HOLD3* [029D,1] -- Temporary storage

B33 TMPCHR* [0050,1] -- Temporary storage

B34 DSTAT* [004C,1] -- Display status

B35 DINDEX* [0057,1] -- Display mode

DINDEX contains the current screen mode obtained from the low order four bits of the most recent OPEN AUX1 byte.

B36 SAVMSC* [0058,2] -- Temporary storage — bottom address of screen data, points to byte at upper left corner of screen.

B37 OLDCHR* [005D,1] -- Cursor character save/restore

OLDCHR retains the value of the character under the visible text cursor; this variable is used to restore the original character value when the cursor is moved.

B38 OLDADR* [005E,2] -- Cursor memory address

OLDADR retains the memory address of the current visible text cursor location; this variable is used in conjunction with OLDCHR (B37) to restore the original character value when the cursor is moved.

B39 ADRESS* [0064,2] -- Temporary storage

B40 MLTTMP/OPNTMP/TOADR* [0066,2] -- Temporary storage

B41 SAVADR/FRMADR* [0068,2] -- Temporary storage

B42 BUFCNT* [006B,1] -- Screen Editor current logical line size

B43 BUFSTR* [006C,2] -- Temporary storage

B44 SWPFLG* [007B,1] -- Split screen cursor control

In split screen mode, the graphics cursor data and the text window cursor data are frequently swapped as shown below in order to get the variables associated with the region being accessed into the ROWCRS-OLDADR variables.

```
ROWCRS B2 ------- TXTROW B4
COLCRS B2 ------- TXTCOL B4
DINDEX B35 ------ TINDEX B49
SAVMSC B36 ------ TXTMSC B52
```

```
OLDROW B3 ------- TXTOLD B53
OLDCOL B3 -------   "      "
OLDCHR B37 ------   "      "
OLDADR B38 ------   "      "
```

SWPFLG is used to keep track of which data set is currently in the ROWCRS-OLDADR region; SWPFLG is equal to $FF when split screen text window cursor data is in the main region, otherwise SWPFLG is equal to 0.

B45 INSDAT* [007D,1] -- Temporary storage

B46 TMPROW* [02B8,1] & TMPCOL* [02B9,2] -- Temporary storage

B47 TMPLBT* [02A1,1] -- Temporary storage

B48 SUBTMP* [029E,1] -- Temporary storage

B49 TINDEX* [0293,1] -- Split screen text window screen mode

TINDEX is the split screen text window equivalent of DINDEX and is always equal to zero when SWPFLG is equal to zero (see B44).

B50 BITMSK* [006E,1] -- Temporary storage

B51 LINBUF* [0247,40] -- Physical line buffer

LINBUF is used to temporarily buffer one physical line of text when the Screen Editor is moving screen data.

B52 TXTMSC* [0294,2] -- Temporary storage

See B44 for more information.

split screen text window version of SAVMSC

B53 TXTOLD* [0296,6] -- Split screen cursor data

See B44 for more information.

Internal character code conversion

Two variables are used to retain the current character being processed (for both reading and writing); ATACHR contains the value passed to or from CIO, and CHAR contains the internal code corresponding to the value in ATACHR. Because the hardware does not interpret ATASCII characters directly, the transformations shown below are applied to all text data read and written:

ATASCII CODE	INTERNAL CODE
00-1F	40-5F
20-3F	00-1F
40-5F	20-3F
60-7F	60-7F
80-9F	C0-DF
A0-BF	80-9F
C0-DF	A0-BF
E0-FF	E0-FF

B54 ATACHR [02FB,1] -- Last ATASCII character or plot point

ATACHR contains the ATASCII value for the most recent character read or written, or the value of the graphics point. This variable may also be considered to be a parameter of the FILL/DRAW commands, as the value in ATACHR will determine the line color when a DRAW or FILL is performed.

B55 CHAR* [02FA,1] -- Internal character code

CHAR contains the internal code value for the most recent charcter read or written.

C. DISK HANDLER

See section 5.4.2 for a discussion of the resident Disk handler.

C1 BUFADR* [0015,2] -- Data buffer pointer

BUFADR acts as temporary page zero pointer to the current disk buffer.

C2 DSKTIM* [0246,1] -- Disk format operation timeout time

DSKTIM contains the timeout value for SIO calling sequence variable DTIMLO (see section 9.3.1); DSKTIM is set to 160 (which represents a 171 second timeout) at initialization time, and is updated after each disk status request operation contain the value returned in the 3rd byte of the status frame (see section 5.3.5). Note that all disk operations other than format have a fixed 7.5 second timeout, established by the Disk handler.

D. CASSETTE

See section 5.3.4 for a general description of the Cassette handler. The cassette uses the Serial I/O bus hardware, but does not conform with the Serial I/O bus protocol as defined in section 9.4. Hence, the Serial I/O utility (SIO) has cassette specific code within it. Some variables in this sub-section are utilized by SIO and some by the Cassette handler.

Baud rate determination

The input baud rate is assumed to be a nominal 600 baud, but will be adjusted, if necessary, by the SIO routine to account for drive motor variations, stretched tape, etc. The beginning of every cassette record contains a pattern of alternating ones and zeroes which is used solely for speed correction; by measuring the time to read a fixed number of bits, the true receive baud rate is determined and the hardware adjusted accordingly. Input baud rates ranging from 318 to 1407 baud can theoretically be handled using this technique.

The input baud rate is adjusted by setting the POKEY counter which controls the bit sampling period.

D1 CBAUDL* [02EE,1] & CBAUDH* [02EF,1] -- Cassette baud rate

Initialized to 05CC hex, which represents a nominal 600 baud. After baud rate calculation, these variables will contain POKEY counter values for the corrected baud rate.

D2 TIMFLG* [0317,1] -- Baud rate determination time out flag

TIMFLG is used by SIO to timeout an unsuccessful baud rate determination. The flag is initially set to one, and if it attains a value of zero (after 2 seconds) before the first byte of the cassette record has been read, the operation will be aborted. See also H24.

D3 TIMER1* [030C,2] & TIMER2* [0310,2] -- Baud rate timers

These timers contain reference times for the beginning and end of the fixed bit pattern receive period. The first byte of each timer contains the then current vertical line counter value read from ANTIC, and the second byte of each timer contains the then current value of the least significant byte of the O.S. real time clock (RTCLOK+2).

The difference between the timers is converted to raster pair counts and is then used to perform a table lookup with interpolation to determine the new values for CBAUDL and CBAUDH.

D4 ADDCOR* [030E,1] -- Interpolation adjustment variable

ADDCOR is a temporary variable used for the interpolation calculation of the above computation.

D5 TEMP1* [0312,2] -- Temporary storage

D6 TEMP3* [0315,1] -- Temporary storage

D7 SAVIO* [0316,1] -- Serial in data detect

SAVIO is used to retain the state of SKSTAT [D20F] bit-4 (serial data in); it is used to detect (and is updated after) every bit arrival.

Cassette mode

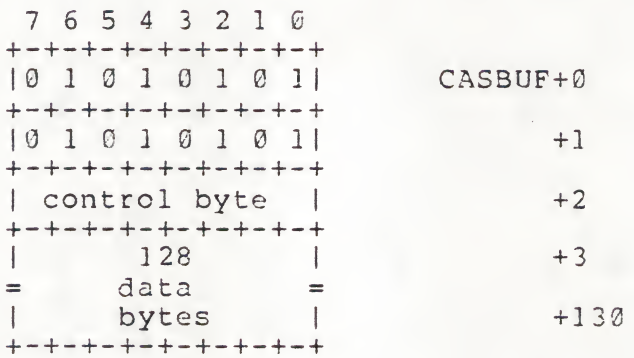
D8 CASFLG* [030F,1] -- Cassette I/O flag

CASFLG is used internally by SIO to control the program flow through shared code. A value of zero indicates that the current operation is a standard Serial I/O bus operation, and a non-zero value indicates a cassette operation.

Cassette buffer

D9 CASBUF* [03FD,131] -- Cassette record buffer

CASBUF is the buffer used by the Cassette handler for the packing and unpacking of cassette record data, and by the initialization cassette boot logic. The format for the standard cassette record in the buffer is shown below:



See section 5.3.4 for an explanation of the standard cassette record format.

D10 BLIM* [028A,1] -- Cassette record data size

BLIM contains the count of the number of data bytes in the current cassette record being read. BLIM will have a value ranging from 1 to 128, depending upon the record control byte as explained in section 5.3.4.

D11 BPTR* [003D,1] -- Cassette record data index

BPTR contains an index into the data portion of the cassette record being read or written. The value will range from 0 to the then current value of BLIM. When BPTR equals BLIM then the buffer (CASBUF) is full if writing or empty if reading.

Internal working varibles

D12 FEOF* [003F,1] -- Cassette end of file flag

FEOF is used by the cassette handler to flag the detection of an

end of file condition (control byte = $FE). FEOF equal to zero indicates that an EOF has not yet been detected, and a non-zero value indicates that an EOF has been detected. The flag is reset at every OPEN.

D13 FTYPE* [003E,1] -- Inter-record gap type

FTYPE is a copy of ICAX2Z from the OPEN command and indicates the type of inter-record gap selected; a positive value indicates normal record gaps, and a negative value indicates continuous mode gaps.

D14 WMODE* [0289,1] -- Cassette read/write mode flag

WMODE is used by the cassette handler to indicate whether the current operation is a read or write operation; a value of zero indicates read, and a value of $80 indicates write.

D15 FREQ* [0040,1] -- Beep count

FREQ is used to retain and count the number of beeps requested of the 'BEEP' routine by the Cassette handler during the OPEN command process.

E. KEYBOARD

See section 5.3.1 for a general description of the Keyboard handler.

Key reading and debouncing

The console key code register is read in response to an IRQ interrupt which is generated whenever a key stroke is detected by the hardware. The key code is compared with the prior key code accepted (CH1); if the codes are not identical, then the new code is accepted and stored in the key code FIFO (CH) and in the prior key code variable (CH1). If the codes are identical, then the new code is accepted only if a suitable key debounce delay has transpired since the prior value was accepted.

If the key code read and accepted is the code for CTRL-1, then the display start/stop flag (SSFLAG) is complemented and the value is not stored in the key code FIFO (CH).

In addition to the reading of the key data, SRTIMR is set to $30 for all interrupts received (see E8), and ATRACT is set to 0 whenever a new code is accepted (see B10).

The Keyboard handler obtains all key data from CH; whenever a code is extracted from that one-byte FIFO, the handler stores a value of $FF to the FIFO to indicate that the code has been read. See section 5.3.1 for further discussion of the Keyboard handler's processing of the key codes.

E1 CH1* [02F2,1] -- Prior keyboard character code.

CH1 contains the key code value of the key most recently read and accepted.

E2 KEYDEL* [02F1,1] -- Debounce delay timer.

KEYDEL is set to a value of 3 whenever a key code is accepted, and is decremented every 60th of a second by the stage 2 VBLANK process (until it reaches zero).

E3 CH [02FC,1] -- Keyboard character code FIFO.

CH is a one-byte FIFO which contains either the value of the most recently read and accepted key code or the value $FF (which indicates that the FIFO is empty). The FIFO is normally read by the keyboard handler, but may be read by a user program.

Key data may also be stored into CH by the auto-repeat logic as explained in the discussion relating to E8.

Special functions

Start/stop

Display handler and Screen Editor output to the text or graphics mode screen may be stopped and started (without losing any of the output data) through the use of the CTRL-1 key combination. Each key depression toggles a flag which is monitored by the above mentioned handlers. When the flag is non-zero, the handlers wait for it to go to zero before continuing any output.

E4 SSFLAG [02FF,1] -- Start/stop flag

The flag is normally zero, indicating that screen output is not to be stopped. The flag is complemented by every occurrence of the CTRL-1 key combination by the keyboard IRQ service routine.

The flag is set to zero upon power-up, RESET or BREAK key processing.

BREAK key

E5 BRKKEY [0011,1] -- BREAK key flag

BRKKEY is used to indicate that the BREAK key has been pressed. The value is normally non-zero and is set to zero whenever the BREAK key is pressed. The code that detects and processes the BREAK condition (flag = 0) should set the flag non-zero again.

BRKKEY is monitored by the following O.S. routines: Keyboard handler, Display handler, Screen Editor, Cassette handler, xx? The detection of a BREAK condition during an I/O operation, will cause the operation to be aborted and a status of $80 to be returned to the user.

The flag is set non-zero upon power-up, RESET or upon aborting a pending I/O operation.

SHIFT/CONTROL lock

The keyboard control has three different modes for code generation which apply to the alphabetic keys 'A' through 'Z': 1) normal, 2) caps lock and 3) control lock.

In normal mode, all unmodified alphabetic character keys generate the lower case letter ATASCII code ($61-7A).

In caps lock mode, all unmodified alphabetic character keys generate the upper case letter ATASCII code ($41-5A).

In control lock mode, all unmodified alphabetic character keys generate the control letter ATASCII code ($01-1A).

In all three modes, any alphabetic character key which is modified (by being pressed in conjunction with the SHIFT or CONTROL key) will generate the desired modified code.

E6 SHFLOK [02BE,1] -- Shift/control lock control flag

SHFLOK normally has one of three values:

$00 = normal mode (no locks in effect).
$40 = caps lock.
$80 = control lock.

SHFLOK is set to $40 upon power-up and reset and is modified thereafter by the O.S. only when the CAPS key is pressed (either by itself or in conjunction with the SHIFT or CTRL key).

E7 HOLDCH* [007C,1] -- Character holding variable

HOLDCH is used to retain the current character value prior to the SHIFT/CONTROL logic process.

Auto-repeat

The auto-repeat feature responds to the continuous depression of a keyboard key by replicating the key code 10 times per second, after an initial 1/2 second delay. The timer variable SRTIMR is used to control both the initial delay and the repeat rate.

Whenever SRTIMR is equal to zero and a key is being held down, the value of the key code is stored in the key code FIFO (CH). This logic is part of the stage 2 VBLANK process.

E8 SRTIMR* [022B,1] -- auto-repeat timer

SRTIMR is controlled by two independent processes: 1) the keyboard IRQ service routine, which establishes the initial delay value and 2) the stage 2 VBLANK routine which establishes the repeat rate, decrements the timer and implements the auto-repeat logic.

Inverse video control

The Keyboard handler allows the direct generation of a more than half of the 256 ATASCII codes; but codes $80-9A and codes $A0-FC can be generated only with the "inverse video mode" active. The Atari key acts as an on/off toggle for this mode, and all characters (except for screen editing control characters) will be subject to inversion when the mode is active.

E9 INVFLG [02B6,1] -- inverse video flag

INVFLG is normally zero, indicating that normal video ATASCII codes (bit-7 = 0) are to be generated from keystrokes; however, whenever INVFLG is non-zero, inverse video ATASCII codes (bit-7 = 1) will be generated. The special control codes are exempt from this bit manipulation.

INVFLG is set to zero by power-up and RESET.

The Keyboard handler inverts bit-7 of INVFLG whenever the Atari key is pressed; the lower order bits are not altered and are assumed to be zero.

The Keyboard handler "exculsive or"s the ATASCII key data with the value in INVFLG at all times; the normal values of $00 and $80 thus lead to control of the inverse video bit (bit-7).

Console switches (SELECT, START & OPTION)

The console switches are sensed directly from the hardware register CONSOL [D01F]; see the Colleen hardware manual for details.

F. PRINTER

See section 5.3.5 for a general description of the Printer handler.

Printer buffer

F1 PRNBUF* [03C0,40] -- Printer record buffer

PRNBUF is the buffer used by the Printer handler for packing printer data to be sent to the device controller. The buffer is 40 bytes long and contains nothing but printer data.

F2 PBUFSZ* [001E,1] -- Printer record size

PBUFSZ contains the size of the printer record for the current mode selected; the modes and respective sizes (in decimal bytes) are shown below:

Normal	40	
Double width	20	(not currently supported by the device)
Sideways	29	
Status request	4	

F3 PBPNT* [001D,1] -- Printer buffer index

PBPNT contains the current index to the printer buffer. PBPNT ranges in value from zero to the value of PBUFSZ.

Internal working variables

F4 PTEMP* [001F,1] -- Printer handler temporary data save

PTEMP is used by the Printer handler to temporarily save the value of a character to be output to the printer.

F5 PTIMOT* [001C,1] -- Printer timeout value

PTIMOT contains the timeout value for SIO calling sequence variable DTIMLO (see section 9.3.1); PTIMOT is set to 30 (which represents a 32 second timeout) at intialization time, and is updated after each printer status request operation to contain the value returned in the 3rd byte of the status frame (see section 5.3.5).

G. CENTRAL I/O ROUTINE (CIO)

See section 5 for a description of the Central I/O Utility.

User call parameters

CIO call paramters are passed primarily through an I/O Control Block (IOCB); although additional device status information may be returned in DVSTAT, and handler information is obtained from the Device Table (HATABS).

I/O Control Block

IOCB is the name applied collectively to the 16 bytes associated with each of the 8 provided control structures; see section 5.2.2.

G1 IOCB [0340,16] -- I/O Control Block

The label IOCB is the location of the first byte of the first IOCB in the data base. For VIDs G2 through G10, the addresses given are for IOCB #0 only, the addresses for all of the IOCBs are shown below:

0340-034F	IOCB #0
0350-035F	IOCB #1
0360-036F	IOCB #2
0370-037F	IOCB #3
0380-038F	IOCB #4
0390-039F	IOCB #5
03A0-03AF	IOCB #6
03B0-03BF	IOCB #7

G2 ICHID [0340,1] -- Handler I.D.

See section 5.2.2. Initialized to $FF at power-up and RESET.

G3 ICDNO [0341,1] -- Device number

See section 5.2.2.

G4 ICCOM [0342,1] -- Command byte

See section 5.2.2.

G5 ICSTA [0343,1] -- Status

See section 5.2.2.

G6 ICBAL,ICBAH [0344,2] -- Buffer address

See section 5.2.2.

G7 ICPTL,ICPTH [0346,2] -- PUT BYTE vector

See section 5.2.2. Initialized to point to CIO's "IOCB not OPEN" routine at power-up and RESET.

G8 ICBLL,ICBLH [0348,2] -- Buffer length / byte count

See section 5.2.2.

G9 ICAX1,ICAX2 [034A,2] -- Auxilliary information

See section 5.2.2.

G10 ICSPR [034C,4] -- Spare bytes for handler use

There is no fixed assignment of these four bytes; the handler associated with an IOCB may or may not use these bytes.

Device status

G11 DVSTAT [02EA,4] -- Device status

See section 5.2.3 for a discussion of the GET STATUS command.

Device Table

G12 HATABS [031A,38] -- Device Table

See section 9.1 for a description of the Device Table.

CIO/handler interface parameters

Communication between CIO and a handler is accomplished using the 6502 machine registers, and a data structure called the zero page IOCB (ZIOCB). The ZIOCB is essentially a copy of the particular IOCB being used for the current operation.

Zero page IOCB

G13 ZIOCB (IOCBAS) [0020,16] -- Zero page IOCB

The zero page IOCB is an exact copy (except as noted in the discussions that follow) of the IOCB specified by the 6502 X register upon entry to CIO; CIO copies the outer level IOCB to the zero page IOCB, performs the indicated function, moves the (possibly altered) zero page IOCB back to the outer level IOCB, and then returns to the caller.

Although both the outer level IOCB and the zero page IOCB are defined to be 16 bytes in size, only the first 12 bytes are moved by CIO.

G14 ICHIDZ [0020,1] -- Handler index number

See section 5.2.2. Set to $FF on CLOSE.

G15 ICDNOZ [0021,1] -- Device drive number

See section 5.2.2.

G16 ICCOMZ [0022,1] -- Command byte

See section 5.2.2.

G17 ICSTAZ [0023,1] -- Status byte

See section 5.2.2.

G18 ICBALZ,ICBALH [0024,2] -- Buffer address

See section 5.2.2. This pointer variable is modified by CIO in the course of processing some commands; however, the original value is restored before returning to the caller.

G19 ICPTLZ,ICPTHZ [0026,2] -- PUT BYTE vector

See section 5.2.2. Set to point to CIO's "IOCB not OPEN" routine on CLOSE.

G20 ICBLLZ,ICBLHZ [0028,2] -- Buffer length / byte count

See section 5.2.2. This double byte variable, which starts out representing the buffer length, is modified by CIO in the course of processing some commands; then, before returning to the caller, the transaction byte count is stored therein.

G21 ICAX1Z,ICAX2Z [002A,2] -- Auxilliary information

See section 5.2.2.

G22 ICSPRZ (ICIDNO,CIOCHR) [002C,4] -- CIO working variables

ICSPRZ and ICSPRZ+1 are used by CIO in obtaining the appropriate handler entry point from the handler's vector table (see sections 9.1 and 9.2).

ICSPRZ+2 is also labeled ICIDNO and retains the value of the 6502 X register from CIO entry. The X register is loaded from ICIDNO as CIO returns to the caller.

ICSPRZ+3 is also labeled CIOCHR and retains the value of the 6502 A register from CIO entry, except for data reading type commands, in which case the most recent data byte read is stored in CIOCHR. The 6502 A register is loaded from CIOCHR as CIO returns to the caller.

Internal working variables

G23 ICCOMT* [0017,1] -- Command table index

ICCOMT is used as an index to CIO's internal command table, which maps command byte values to handler entry offsets (see section 9.2 for more information). ICCOMT contains the value from ICCOMZ except when ICCOMZ is greater than $0E, in which case ICCOMT is set to $0E.

G24 ICIDNO* [002E,1] -- CIO call X register save/restore

See G22.

G25 CIOCHR* [002F,1] -- CIO call A register save/restore

See G22.

H. SERIAL I/O ROUTINE (SIO)

See section 9 and specifically 9.3 for discussions relating to SIO.

User call parameters

SIO call parameters are passed primarily through a Device Control Block; although an additional "noisy bus" option exists which is selectable through a separate variable.

Device Control Block

H1 DCB [0300,12] -- Device Control Block

DCB is the name applied collectively to the 12 bytes at locations 0300-030B. These bytes provide the parameter passing mechanism for SIO and are described individually below.

H2 DDEVIC [0300,1] -- Device bus I.D.

See section 9.3.1.

H3 DUNIT [0301,1] -- Device unit number

See section 9.3.1.

H4 DCOMND [0302,1] -- Device command

See section 9.3.1.

H5 DSTATS [0303,1] -- Device status

See section 9.3.1.

H6 DBUFLO,DBUFHI [0304,2] -- Handler buffer address

See section 9.3.1.

H7 DTIMLO [0306,1] -- Device timeout

See section 9.3.1.

H8 DBYTLO,DBYTHI [0308,2] -- Buffer length / byte count

See section 9.3.1.

H9 DAUX1,DAUX2 [030A,2] -- Auxilliary information

See section 9.3.1.

Bus sound control

H10 SOUNDR [0041,1] -- Quiet/noisy I/O flag

SOUNDR is a flag used to indicate to SIO whether noise is to be generated on the TV audio circuit when Serial I/O bus activity is in progress. SOUNDR equal to zero indicates that sound is to be inhibited, and non-zero indicates that sound is to be enabled. SIO sets SOUNDR to 3 at power-up and RESET.

Serial bus control

Retry logic

SIO will attempt one complete command retry if the first attempt is not error free, where a complete command try consists of up to 14 attempts to send (and acknowledge) a command frame, followed by a single attempt to receive COMPLETE and possibly a data frame.

H11 CRETRY* [0036,1] -- Command frame retry counter

CRETRY controls the inner loop of the retry logic, that associated with sending and receiving an acknowledgement of the command frame. CRETRY is set to 13 by SIO at the beginning of every command initiation, thus allowing for an initial attempt and up to 13 additional retries.

H12 DRETRY* [0037,1] -- Device retry counter

DRETRY controls the outer loop of the retry logic, that associated with initiating a command retry after a failure subsequent to the command frame acknowledgement. DRETRY is set to 1 by SIO at entry, thus allowing for an initial attempt and up to 1 additional retry.

Checksum

The Serial I/O bus protocol specifies that all command and data frames must contain a checksum validation byte; this byte is the arithmetic sum (with end-around carry) of all of the other bytes in the frame.

H13 CHKSUM* [0031,1] -- Checksum value

CHKSUM contains the frame checksum as computed by SIO for all frame transfers.

H14 CHKSNT* [003B,1] -- Checksum sent flag

CHKSNT indicates to the serial bus transmit interrupt service routine whether the frame checksum byte has been sent yet. CHKSNT equal to zero indicates that the checksum byte has not yet been sent; after the checksum is sent, CHKSNT is then set non-zero.

H15 NOCKSM* [003C,1] -- No checksum follows data flag

NOCKSM is a flag used to communicate between the SIO top level code and the Serial bus receive interrupt service routine that the next input will not be followed by a checksum byte. A value of zero specifies that a checksum byte will follow, non-zero that a checksum byte will not follow.

Data buffering

General buffer control

H16 BUFRLO* [0032,1] & BUFRHI* [0033,1] -- Next byte address

BUFRLO and BUFRHI comprise a pointer to the next buffer location to be read from or written to. For a data frame transfer, the pointer is initially set to the value contained in the SIO call parmaters DBUFLO and DBUFHI, and is then incremented by the interrupt service routines as a part of normal bus data transfer. For a command frame transfer, the pointer is set to point to the SIO maintained command frame output buffer.

H17 BFENLO* [0034,1] & BFENHI* [0035,1] -- Buffer end address

BFENLO/BFENHI form a pointer to the the byte following the last frame data byte (not including the checksum) to be sent or received. BFENLO/BFENHI is the arithmetic sum of BUFRLO/BUFRHI plus the frame size plus -1.

Command frame output buffer

See section 9.4.2 for the command frame format and description.

H18 CDEVIC* [023A,1] -- Command frame device I.D.

CDEVIC is set to the value obtained by adding SIO call parameter DDEVIC to DUNIT and subtracting one.

H19 CCOMND* [023B,1] -- Command frame command.

CCOMND is set to the value obtained from SIO call parameter DCOMND.

H20 CAUX1* [023C,1] & CAUX2* [023D,1] -- Auxilliary info

CAUX1 and CAUX2 are set to the values obtained from SIO call parameters DAUX1 and DAUX2, respectively.

Receive/transmit data buffering

H21 BUFRFL* [0038,1] -- Buffer full flag

BUFRFL is a flag used by the serial bus receive interrupt service routine to indicate when the main portion of a bus frame has been received -- all but the checksum byte. BUFRFL equal to zero indicates that the main portion has not been completely received, a non-zero value indicates that the main portion has been received.

H22 RECVDN* [0039,1] -- Receive frame done flag

RECVDN is a flag used by SIO to communicate between the Serial bus receive interrupt service routine and the main SIO code. The flag is initially set to zero by SIO, and later set non-zero by the interrupt service routine after the last byte of a bus frame has been received.

H23 TEMP* [023E,1] -- SIO one-byte I/O data

TEMP is used to receive one-byte responses from serial bus controllers, such as ACK, NAK, COMPLETE or ERROR.

H24 XMTDON* [003A,1] -- Transmit frame done flag

XMTDON is a flag used by SIO to communicate between the Serial bus transmit interrupt service routine and the main SIO code. The flag is initially set to zero by SIO, and later set non-zero by the interrupt service routine after the last byte of a bus frame has been transmitted.

SIO timeout

SIO uses system timer 1 to provide the timeout capability for various operations initiated internally. See section 6.6 for a discussion of the capabilities of the system timers. TIMFLG is the flag used to communicate between SIO and the timer initiated code pointed to by CDTMA1.

H25 TIMFLG* [0317,1] -- SIO operation timeout flag

TIMFLG is used to indicate a timeout situation for a bus operation . The flag is initially set to one, and if it attains a value of zero (after the timeout period) before the current operation is complete, the operation will be aborted. See also D2.

H26 CDTMV1* [0218,2] -- System timer 1 value

This two-byte count takes on various values depending upon the operation being timed. See also P4.

H27 CDTMA1* [0226,2] -- System timer 1 address

This vector always points to the 'JTIMER' routine, whose only function is to set TIMFLG to zero. This vector is initialized by SIO before every use, so that system timer 1 may be used by any process that does not use SIO within a timing function. See also P5.

Internal working variables

H28 STACKP* [0318,1] -- Stack pointer save/restore

STACKP contains the value of the 6502 SP register at entry to SIO; this is retained to facilitate a direct error exit from an SIO subroutine.

H29 TSTAT* [0319,1] -- Temporary status

TSTAT is used to return the operation status from the 'WAIT' routine and will contain one of the SIO status byte values as shown in Appendix B.

H30 ERRFLG* [023F,1] -- I/O error flag

ERRFLG is used for communication between the 'WAIT' routine and the outer level SIO code. ERRFLG is normally zero, but is set to $FF when a device responds with an invalid response byte.

H31 STATUS* [0030,1] -- SIO operation status

STATUS is a zero page variable that is used within SIO to contain the operation status that will be stored to the calling sequence parameter variable DSTATS when SIO returns to the

caller.

H32 SSKCTL* [0232,1] -- SKCTL copy

SSKCTL is utilized by SIO to keep track of the content of the SKCTL [D20F] register which is a write only register.

J. ATARI CONTROLLERS

Various of the Atari controllers are read as part of the Stage 2 VBLANK process; the encoded data is partially decoded and processed as shown in the sub-sections that follow.

Joysticks

Up to 4 joystick controllers may be attached to the computer, each with a 9 position joystick plus a trigger button.

J1 STICK0 - STICK3 [0278,4] -- Joystick position sense

The four joystick position sense variables contain a bit encoded position sense as shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
|0 0 0 0|R|L|D|U|
+-+-+-+-+-+-+-+-+
```

where: R = 0 indicates joystick RIGHT sensor true.
L = 0 indicates joystick LEFT sensor true.
D = 0 indicates joystick DOWN sensor true.
U = 0 indicates joystick UP sensor true.

Nine unique combinations are possible, indicating the possible joystick positions shown below:

CENTER	$0F (hexadecimal)
UP	0E
UP/RIGHT	06
RIGHT	07
DOWN/RIGHT	05
DOWN	0D
DOWN/LEFT	09
LEFT	0B
UP/LEFT	0A

J2 STRIG0 - STRIG3 [0284,4] -- Joystick trigger sense

The four joystick trigger sense variables each contain a single bit indicating the position of the joystick trigger as shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
|0 0 0 0 0 0 0|T|
+-+-+-+-+-+-+-+-+
```

where: T = 0 indicates trigger pressed.

Paddles

Up to eight paddle controllers may be connected to the computer, each with a potentiometer and a trigger sense.

J3 PADDLØ - PADDL7 [0270,8] -- Paddle position sense

There is a single byte variable associated with each paddle position sense; the values range from 228 for full counterclockwise rotation to 1 for full clockwise rotation.

The paddle values are often converted by the user, as shown below, to give a result of Ø for full counterclockwise rotation and 227 for full clockwise rotation:

```
VALUE := 228 - PADDLX;
```

J4 PTRIGØ - PTRIG7 [027C,8] -- Paddle trigger sense

The eight paddle trigger sense variables each contain a single bit indicating the position of the paddle trigger as shown below:

```
 7 6 5 4 3 2 1 Ø
+-+-+-+-+-+-+-+-+
|Ø Ø Ø Ø Ø Ø Ø|T|
+-+-+-+-+-+-+-+-+
```

where: T = Ø indicates trigger pressed.

Light pen

The O.S. reads the position of a single light pen and stores the horizontal and vertical position codes in two variables; these codes are not the same as the actual screen coordinates. The pen position codes for different portions of the screen are shown below:

Left edge -- 67.
Codes increase monotonically to a value of 227, then go to Ø and continue to increase monotonically (one count per color clock).
Right edge -- 7.

Upper edge -- 16.
Codes increase monotonically (one count per two raster lines).
Lower edge -- 111.

The light pen hardware will read and latch the pen position 60 times per second, independent of the pen button position, which is separately sensed.

In order for the light pen to operate it must be positioned over a portion of the screen which has sufficient luminance to activate the photosensor in the pen; a blank (dark) screen will generally not provide enough luminance to utilize the light pen.

J5 LPENH [0234,1] -- Light pen horizontal position code

LPENH contains the horizontal position code for the light pen; the algorithm below (written in Pascal) shows the conversion from position code to screen coordinate (screen mode 7):

```
IF LPENH < 33       { check for rollover point }
   THEN             { adjust values to right of rollover }
      XPOS := LPENH + 227
   ELSE             { no adjustment to left of rollover point }
      XPOS := LPENH;
XPOS := XPOS - 67; { adjust for left edge offset }
IF XPOS < 0 THEN XPOS := 0;
IF XPOS > 159 THEN XPOS := 159;
```

J6 LPENV [0235,1] -- Light pen vertical position code

LPENV contains the vertical position code for the light pen; the algorithm below (written in Pascal) shows the conversion from position code to screen coordinate (screen mode 7):

```
YPOS := LPENV - 16; { adjust for upper edge offset }
IF YPOS < 0 THEN YPOS := 0;
IF YPOS > 95 THEN YPOS := 95;
```

J7 STICK0 [0278,1] -- Lightpen button sense

The lightpen button sense is encoded in STICK0 as shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
|0 0 0 0|? ? ?|T|
+-+-+-+-+-+-+-+-+
```

where: T = 0 indicates the lightpen button is pressed.

Driving controllers

The driving controller has no position stops and thus allows unlimited rotation in either direction; the output of the controller is a 2-bit Gray code which can be used to determine the direction of rotation. The controller is sensed using the same internal hardware as the joystick, thus the same data base variables are used for both.

J8 STICK0 - STICK3 [0278,4] -- Driving controller sense

The four driving controller sense variables contain an encoded rotation (position) sense value, as shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
|0 0 0 0 1 1|val|
+-+-+-+-+-+-+-+-+
```

where a clockwise rotation of the controller produces the following continuous sequence of four values (shown in hexadecimal):

0F,0D,0C,0E,0F,0D,.....

and a counterclockwise rotation of the controller produces the

following continuous sequence of four values:

    0F,0E,0C,0D,0F,0E,.....

J9 STRIG0 - STRIG3 [0284,4] -- Driving trigger sense

The four driving trigger sense variables each contain a single bit indicating the position of the driving trigger as shown below:

```
  7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
|0 0 0 0 0 0 0|T|
+-+-+-+-+-+-+-+-+
```

where: T = 0 indicates trigger pressed.

K. DISK FILE MANAGER

See section 5.3.6 for information relating to the Disk File Manager.

K1 FMSZPG* [0043,7] -- FMS reserved space

FMSZPG is the reserved space in the database for the variables shown below; the names associated with K2 through K5 are not in the system equate file.

K2 ZBUFP* [0043,2] -- Buffer pointer

K3 ZDRVA* [0045,2] -- Drive pointer

K4 ZSBA* [0047,2] -- Sector buffer pointer

K5 ERRNO* [0049,1] -- Error number

L. DISK UTILITIES (DOS)

L1 DSKUTL* [001A,2] -- Page zero pointer variable

M. FLOATING POINT PACKAGE

See section 8 for a description of the Floating Point Package.

M1 FR0 [00D4,6] -- F.P. register 0

M2 FRE* [00DA,6] -- F.P. register (internal)

M3 FR1 [00E0,6] -- F.P. register 1

M4 FR2* [00E6,6] -- F.P. register 2 (internal)

M5 FRX* [00EC,1] -- Spare (unused)

M6 EEXP* [00ED,1] -- Exponent value (internal)

M7 NSIGN* [00EE,1] -- Sign of mantissa (internal)

M8 ESIGN* [00EF,1] -- Sign of exponent (internal)

M9 FCHRFLG* [00F0,1] -- First character flag (internal)

M10 DIGRT* [00F1,1] -- Digits to right of decimal point

M11 CIX [00F2,1] -- Character index

M12 INBUFF [00F3,2] -- Input text buffer pointer

M13 ZTEMP1* [00F5,2] -- Temporary storage

M14 ZTEMP4* [00F7,2] -- Temporary storage

M15 ZTEMP3* [00F9,2] -- Temporary storage

M16 FLPTR [00FC,2] -- Pointer to F.P. number

M17 FPTR2* [00FE,2] --

M18 LBPR1* [057E,1] -- LBUFF preampbe

M19 LBPR2* [057F,1] -- LBUFF preamble

M20 LBUFF [0580,96] -- Text buffer

M21 PLYARG* [05E0,6] -- F.P. register (internal)

M22 FPSCR/FSCR* [05E6,6] -- F.P. register (internal)

M23 FPSCR1/SCR1* [05EC,6] -- F.P. register (internal)

M24 DEGFLG/RADFLG [00FB,1] -- Degrees/radians flag

DEGFLG = 0 indicates radians, 6 indicates degrees.

N. POWER-UP & RESET

See section 7 for details of the power-up and RESET operations.

RAM sizing

During power-up and RESET the first non-RAM address above 1000 hex is located and its address retained using a non- destructive test. The first byte of every 4K memory "block" is tested to see if it is alterable; if so, the original value is restored and the next block is tested, and if not, that address is considered to be the end of RAM.

N1 RAMLO*/TRAMSZ* [0004,3] -- RAM data/test pointer (temporary)

RAMLO+1 contains the lsb of the address to be tested (always = 0) and TRAMSZ (same as RAMLO+2) contains the msb of the address to be tested. RAMLO+0 contains the complemented value of the

data originally contained in the memory location being tested.

Later in the initialization process these variables are used for totally unrelated functions; but first the value in TRAMSZ is moved to the variables RAMSIZ and MEMTOP+1.

N2 TSTDAT* [0007,1] -- Test data byte save

TSTDAT contains the original value of the memory location being tested.

Disk/cassette boot

As a part of the power-up sequence, software may be booted from an attached disk drive or cassette player as explained in sections 10.2 and 10.3.

N3 DOSINI [000C,2] -- Disk boot initialization vector.

DOSINI contains the disk booted software initialization address from the beginning of the boot file (see section 10.2.1) whenever a disk boot is successfully completed.

N4 CKEY* [004A,1] -- Cassette boot request flag

CKEY is an internal flag used to indicate that the console START key was pressed during power-up, thus indicating that a cassette boot is desired. CKEY equals zero when no cassette boot is requested, and is non-zero when a cassette boot is requested. The flag is cleared to zero after a cassette boot.

N5 CASSBT* [004B,1] -- Cassette booting flag

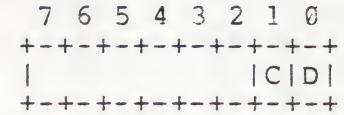
CASSBT is used during the cassette boot process to indicate to shared code that the cassette is being booted and not the disk. CASSBT equal to zero indicates a disk boot, and non-zero indicates a cassette boot.

N6 CASINI [0002,2] -- Cassette boot initialization vector

CASINI contains the cassette booted software initialization address from the beginning of the boot file (see section 10.3.1) whenever a cassette boot is successfully completed.

N7 BOOT?* [0009,1] -- Successful disk/cassette boot flag.

BOOT? indicates to the initialization processor which, if any, of the boot operations went to successful completion. The flag values are set by the O.S. and the format for the variable is shown below:



where: C = 1 indicates that the cassette boot went to completion.
D = 1 indicates that the disk boot went to completion.

N8 DFLAGS* [0240,1] -- Disk flags

DFLAGS contains the value of the first byte of the boot file, after a disk boot. See sections 10.2.1 and 10.2.2.

N9 DBSECT* [0241,1] -- Disk boot sector count

DBSECT is initially set to the value of the second byte of the boot file, during a disk boot, and is then used to control the number of additional disk sectors read, if any.

N10 BOOTAD* [0242,2] -- Disk boot memory address

BOOTAD is initially set to the value of the 3rd and 4th bytes of the boot file, during a disk boot, and is not modified thereafter.

Environment control

If, at the end of a power-up or RESET, control is not given to one of the cartridges (as explained in sections 7 and 10), then program control passes to the address contained in the data base variable DOSVEC.

N11 COLDST* [0244,1] -- Coldstart complete flag

COLDST is used by the initialization routine to detect the case of a RESET occurring before the completion of the power-up process. COLDST is set to $FF at the beginning of the power-up sequence and is set to 0 at the completion; if a RESET occurs while the value is non-zero, the power-up sequence will be reinitiated (rather than initiating a RESET sequence).

N12 DOSVEC [000A,2] -- Non-cartridge control vector

At the beginning of power-up the O.S. sets DOSVEC to point to the "blackboard" routine; DOSVEC may then be altered as a consequence of a disk boot or cassette boot (as explained in section 10) to establish a new control program. Control will be passed through DOSVEC on all power-up and RESET conditions in which a cartridge does not take control first.

RESET

N13 WARMST [0008,1] -- Warmstart flag

WARMST equals $FF during a RESET (warmstart) initialization and equals 0 during a power-up initialization (coldstart).

P. INTERRUPTS

See section 6 for a discussion of interrupt processing.

P1 CRITIC [0042,1] -- Critical code section flag

CRITIC is used to signal to the VBLANK interrupt processor that a critical code section is executing without IRQ interrupts being inhibited; the VBLANK interrupt processor will stop interrupt processing after stage 1 and before stage 2, just as if the 6502 processor I bit were set, when CRITIC is set.

CRITIC equal to zero indicates that the currently executing code section is non-critical, while any non-zero value indicates that the currently executing code section is critical.

P2 POKMSK [0010,1] -- POKEY interrupt mask

POKMSK is a software maintained interrupt mask that is used in conjunction with the enabling and disabling of the various POKEY interrupts. This mask is required because the POKEY interrupt enable register IRQEN [D20E] is a write only register, and at any point in time the system may have several users independently enabling and disabling POKEY interrupts. POKMSK is updated by the users to always contain the current content of IRQEN. See paragraph 6.7.1.

System timers

The system timers are discussed in detail in sections 6.3.1, 6.3.2 and 6.6.

Real time clock

The real time clock (or frame counter, as it is sometimes called) is incremented as part of the stage 1 VBLANK process as explained in section 6.3.1.

P3 RTCLOK [0012,3] -- Real time frame counter

RTCLOK+0 is the most significant byte, RTCLOK+1 the next most significant byte, and RTCLOK+2 the least significant byte. See the discussions at D3 and preceding B10 for O.S. use of RTCLOK.

System timer 1

System timer 1 is maintained as part of the stage 1 VBLANK process, and thus has the highest priority of any of the user timers.

P4 CDTMV1 [0218,2] -- System timer 1 value

CDTMV1 contains zero when the timer is inactive, otherwise it contains the number of VBLANKs remaining until timeout. See also H26.

P5 CDTMA1 [0226,2] -- System timer 1 jump address

CDTMA1 contains the address to which to JSR should the timer timeout. See also H27 and section 6.7.2.

System timer 2

System timer 2 is maintained as part of the stage 2 VBLANK process, and has the second highest priority of the user timers. The O.S. does not have any direct use for system timer 2.

P6 CDTMV2 [021A,2] -- System timer 2 value

CDTMV2 contains zero when the timer is inactive, otherwise it contains the number of VBLANKs remaining until timeout.

P7 CDTMA2 [0228,2] -- System timer 2 jump address

CDTMA2 contains the address to which to JSR should the timer timeout. See section 6.7.2.

System timers 3, 4 and 5

System timers 3, 4 and 5 are maintained as part of the stage 2 VBLANK process, and have the lowest priority of the user timers. The O.S. does not have any direct use for these timers.

P8 CDTMV3 [021C,2], CDTMV4 [021E,2] & CDTMV5 [0220,2]

These variables contain zero when the corresponding timers are inactive, otherwise they contain the number of VBLANKs remaining until timeout.

P9 CDTMF3 [022A,1], CDTMF4 [022C,1] & CDTMF5 [022E,2]

Each of these one-byte variables will be set to zero should its corresponding timer timeout. The O.S. never modifies these bytes except to set them to zero upon timeout (and initialization).

RAM interrupt vectors

There are RAM vectors for many of the interrupt conditions within the system, as explained in section 6. See section 6.7.2 for a discussion of the placing of values to these vectors.

NMI interrupt vectors

P10 VDSLST [0200,2] -- Display list interrupt vector

This vector is not used by the O.S. See sections 6.3 and 6.5.

P11 VVBLKI [0222,2] -- Immediate VBLANK vector

This vector is initialized to point to the O.S. stage 1 VBLANK processor. See sections 6.3 and 6.5.

P12 VVBLKD [0224,2] -- Deferred VBLANK vector

This vector is initialized to point to the O.S. VBLANK exit routine. See sections 6.3 and 6.5.

IRQ interrupt vectors

P13 VIMIRQ [0216,2] -- General IRQ vector

This vector is initialized to point to the O.S. IRQ interrupt processor. See sections 6.4 and 6.5.

P14 VPRCED [0202,2] -- Serial I/O bus proceed signal

The serial bus line that produces this interrupt is not used in the current system. See sections 6.4 and 6.5.

P15 VINTER [0204,2] -- Serial I/O bus interrupt signal

The serial bus line that produces this interrupt is not used in the current system. See sections 6.4 and 6.5.

P16 VBREAK [0206,2] -- BRK instruction vector

This vector is initialized to point to a PLA, RTI sequence as the O.S. proper does not utilize the BRK instruction. See sections 6.4 and 6.5.

P17 VKEYBD [0208,2] -- Keyboard interrupt vector

This vector is initialized to point to the Keyboard handler's interrupt service routine. See sections 6.4, 6.5 and the discussion preceding E1.

P18 VSERIN [020A,2] -- Serial I/O bus receive data ready

This vector is initialized to point to the SIO utility's interrupt service routine. See sections 6.4 and 6.5.

P19 VSEROR [020C,2] -- Serial I/O bus transmit ready

This vector is initialized to point to the SIO utility's interrupt service routine. See sections 6.4 and 6.5.

P20 VSEROC [020E,2] -- Serial I/O bus transmit complete

This vector is initialized to point to the SIO utility's interrupt service routine. See sections 6.4 and 6.5.

P21 VTIMR1 [0210,2], VTIMR2 [0212,2] & VTIMR4 [0214,2] -- POKEY timer vectors

The POKEY timer interrupts are not used by the O.S. See sections 6.4 and 6.5.

Hardware register updates

As part of the stage 2 VBLANK process, certain hardware registers are updated from O.S. database variables as explained in section 6.3.2.

P22 SDMCTL* [022F,1] -- DMA control

SDMCTL is set to a value of $02 at the beginning of a Display handler OPEN command, and then later set to a value of $22. The value of SDMCTL is stored to DMACTL [D400] as part of the stage 2 VBLANK process.

P23 SDLSTL* [0230,1] & SDLSTH* [0231,1] -- Display list address

The Display handler formats a new display list with every OPEN command and puts the display list address in SDLSTL and SDLSTH. The value of these bytes are stored to DLISTL [D402] and DLISTH [D403] as part of the stage 2 VBLANK process.

Note: there is a potential timing problem associated with the updating of the hardware registers from the database variables. Since the stage 2 VBLANK process is performed with interrupts enabled, it is possible for an IRQ interrupt to occur before the updating of DLISTH and DLISTL. If the processing of that interrupt (plus other nested interrupts) exceeds the vertical blank delay (1.5 msec.) then the display list pointer register will not have been updated when display list processing commences for the new frame, and a screen glitch will result.

P24 GPRIOR* [026F,1] -- Priority control

The Display handler alters bits 6 and 7 of GPRIOR as part of establishing the GTIA mode. The value of GPRIOR is stored to PRIOR [D01B] as part of the stage 2 VBLANK process.

P25 CHACT* [02F3,1] -- Character control

The Display handler sets CHACT to $02 on every OPEN command. The value of CHACT is stored to CHACTL [D401] as part of the stage 2 VBLANK process.

P26 CHBAS* [02F4,1] -- Character address base

The Display handler sets CHBAS to $E0 on overy OPEN command. The value of CHBAS is stored to CHBASE [D409] as part of the stage 2 VBLANK process.

P27 PCOLRx [02C0,4] & COLORx [02C4,5] -- Color registers

See B7 and B8.

Internal working variables

P28 INTEMP* [022D,1] -- Temporary storage

INTEMP is used by the SETVBL (SETVBV) routine.

R. USER AREAS

The areas shown below are available to the user in a non-nested environment; see section 4.1 for further information.

R1 [0080,128]

R2 [0480,640]

S. UNUSED (SPARE) BYTES

Labeled bytes

The labeled bytes listed below are thought to: 1) have no function within the O.S. and 2) not be modified except at initialization time.

S1 HOLD5* [02BD,1]

S2 CSTAT* [0288,1]

S3 DUNUSE* [0307,1]

S4 TEMP2* [0314,1]

S5 TMPX1* [029C,1]

S6 DSKFMS* [0018,2]

Unlabeled bytes

The unlabeled bytes and regions listed below are thought to: 1) have no function within the O.S. and 2) not be modified except at initialization time.

S7 [0000,2] Reserved for LNBUG.

S8 [0236,4]

S9 [0245,1]

S10 [028B,5]

S11 [02C9,27]

S12 [02F5,5]

S13 [03E8,21]

S14 [0233,1]

S15 [02E9,1]

ALPHA LIST OF DATABASE VARIABLES

ADDCOR	D4
ADRESS	B39
APPMHI	A3
ATACHR	B54
ATRACT	B10
BFENHI	H17
BFENLO	H17
BITMSK	B50
BLIM	D10
BOOT?	N7
BOOTAD	N10
BOTSCR	B16
BPTR	D11
BRKKEY	E5
BUFADR	C1
BUFCNT	B42
BUFRFL	H21
BUFRHI	H16
BUFRLO	H16
BUFSTR	B43
CASBUF	D9
CASFLG	D8
CASINI	N6
CASSBT	N5
CAUX1	H20
CAUX2	H20
CBAUDH	D1
CBAUDL	D1
CCOMND	H19
CDEVIC	H18
CDTMA1	P5,H27
CDTMA2	P7
CDTMF3	P9
CDTMF4	P9
CDTMF5	P9
CDTMV1	P4,H26
CDTMV2	P6
CDTMV3	P8
CDTMV4	P8
CDTMV5	P8
CH	E3
CH1	E1
CHACT	P25
CHAR	B55
CHBAS	P26
CHKSNT	H14
CHKSUM	H13
CIOCHR	G25,G22
CIX	M11
CKEY	N4
COLAC	B24
COLCRS	B2
COLDST	N11
COLINC	B21
COLOR0	B8,P27

```
COLOR1   B8,P27
COLOR2   B8,P27
COLOR3   B8,P27
COLOR4   B8,P27
COLRSH   B11
COUNTR   B23
CRETRY   H11
CRITIC   P1
CRSINH   B1
CSTAT    S2

DAUX1    H9
DAUX2    H9
DBSECT   N9
DBUFHI   H6
DBUFLO   H6
DBYTHI   H8
DBYTLO   H8
DCB      H1
DCOMND   H4
DDEVIC   H2
DEGFLG   M24
DELTAC   B22
DELTAR   B22
DFLAGS   N8
DIGRT    M10
DINDEX   B35
DMASK    B28
DOSINI   N3
DOSVEC   N12
DRETRY   H12
DRKMSK   B12
DSKFMS   S6
DSKTIM   C2
DSKUTL   L1
DSPFLG   B27
DSTAT    B34
DSTATS   H5
DTIMLO   H7
DUNIT    H3
DUNUSE   S3
DVSTAT   G11

EEXP     M6
ENDPT    B25
ERRFLG   H30
(ERRNO   K5)
ESCFLG   B26
ESIGN    M8

FCHRFL   M9
FEOF     D12
FILDAT   B17
FILFLG   B18
FLPTR    M16
FMSZPG   K1
FPSCR    M22
FPSCR1   M23
FPTR2    M17
FR0      M1
```

```
FR1       M3
FR2       M4
FRE       M2
FREQ      D15
FRMADR    B41
FRX       M5
FSCR      M22
FSCR1     M23
FTYPE     D13

GPRIOR    P24

HATABS    G12
HOLD1     B30
HOLD2     B31
HOLD3     B32
HOLD4     B20
HOLD5     S1
HOLDCH    E7

ICAX1     G9
ICAX1Z    G21
ICAX2     G9
ICAX2Z    G21
ICBAH     G6
ICBAHZ    G18
ICBAL     G6
ICBALZ    G18
ICBLH     G8
ICBLHZ    G20
ICBLL     G8
ICBLLZ    G20
ICCOM     G4
ICCOMT    G23
ICCOMZ    G16
ICDNO     G3
ICDNOZ    G15
ICHID     G2
ICHIDZ    G14
ICIDNO    G24,G22
ICPTH     G7
ICPTHZ    G19
ICPTL     G7
ICPTLZ    G19
ICSPR     G10
ICSPRZ    G22
ICSTA     G5
ICSTAZ    G17
INBUFF    M12
INSDAT    B45
INTEMP    P28
INVFLG    E9
IOCB      G1
IOCBAS    G13

KEYDEL    E2

LBFEND    M20
LBPR1     M18
LBPR2     M19
```

```
LBUFF   M20
LINBUF  B51
LMARGN  B5
LOGCOL  B15
LOGMAP  B14
LPENH   J5
LPENV   J6

MEMLO   A1
MEMTOP  A2
MLTTMP  B40

NEWCOL  B19
NEWROW  B19
NOCKSM  H15
NSIGN   M7

OLDADR  B38
OLDCHR  B37
OLDCOL  B3
OLDROW  B3
OPNTMP  B40

PADDL0  J3
PADDL1  J3
PADDL2  J3
PADDL3  J3
PADDL4  J3
PADDL5  J3
PADDL6  J3
PADDL7  J3
PBPNT   F3
PBUFSZ  F2
PCOLR0  B7,P27
PCOLR1  B7,P27
PCOLR2  B7,P27
PCOLR3  B7,P27
PLYARG  M21
POKMSK  P2
PRNBUF  F1
PTEMP   F4
PTIMOT  F5
PTRIG0  J4
PTRIG1  J4
PTRIG2  J4
PTRIG3  J4
PTRIG4  J4
PTRIG5  J4
PTRIG6  J4
PTRIG7  J4

RADFLG  M24
RAMLO   N1
RAMSIZ  A5
RAMTOP  A4
RECVDN  H22
RMARGN  B6
ROWAC   B24
ROWCRS  B2
ROWINC  B21
```

```
RTCLOK   P3

SAVADR   B41
SAVIO    D7
SAVMSC   B36
SCRFLG   B9
SDLSTH   P23
SDLSTL   P23
SDMCTL   P22
SHFAMT   B29
SHFLOK   E6
SOUNDR   H10
SRTIMR   E8
SSFLAG   E4
SSKCTL   H32
STACKP   H28
STATUS   H31
STICK0   J1,J7,J8
STICK1   J1,J8
STICK2   J1,J8
STICK3   J1,J8
STRIG0   J2,J9
STRIG1   J2,J9
STRIG2   J2,J9
STRIG3   J2,J9
SUBTMP   B48
SWPFLG   B44

TABMAP   B13
TEMP     H23
TEMP1    D5
TEMP2    S4
TEMP3    D6
TIMER1   D3
TIMER2   D3
TIMFLG   D2,H25
TINDEX   B49
TMPCHR   B33
TMPCOL   B46
TMPLBT   B47
TMPROW   B46
TMPX1    S5
TOADR    B40
TRAMSZ   N1
TSTAT    H29
TSTDAT   N2
TXTCOL   B4
TXTMSC   B52
TXTOLD   B53
TXTROW   B4

USAREA   R1

VBREAK   P16
VDSLST   P10
VIMIRQ   P13
VINTER   P15
VKEYBD   P17
VPRCED   P14
VSERIN   P18
```

```
VSEROC   P20
VSEROR   P19
VTIMR1   P21
VTIMR2   P21
VTIMR4   P21
VVBLKD   P12
VVBLKI   P11

WARMST   N13
WMODE    D14

XMTDON   H24

(ZBUFF   K2)
(ZDRVA   K3)
ZIOCB    G13
(ZSBA    K4)
ZTEMP1   M13
ZTEMP3   M15
ZTEMP4   M14
```

MEMORY ADDRESS ORDERED LIST OF DATABASE VARIABLES

0000-0001	S7
0002-0003	N6
0004-0006	N1
0007	N2
0008	N13
0009	N7
000A-000B	N12
000C-000D	N3
000E-000F	A3
0010	P2
0011	E5
0012-0014	P3
0015-0016	C1
0017	G23
0018-0019	S6
001A-001B	L1
001C	F5
001D	F3
001E	F2
001F	F4
0020	G13,G14
0021	G15
0022	G16
0023	G17
0024-0025	G18
0026-0027	G19
0028-0029	G20
002A-002B	G21
002C-002F	G22,G24,G25
0030	H31
0031	H13
0032-0033	H16
0034-0035	H17
0036	H11
0037	H12
0038	H21
0039	H22
003A	H24
003B	H14
003C	H15
003D	D11
003E	D13
003F	D12
0040	D15
0041	H10
0042	P1
0043-0049	K1,K2,K3,K4,K5
004A	N4
004B	N5
004C	B34
004D	B10
004E	B12
004F	B11
0050	B33
0051	B30
0052	B5

0053	B6
0054-0056	B2
0057	B35
0058-0059	B36
005A-005C	B3
005D	B37
005E-005F	B38
0060-0062	B19
0063	B15
0064-0065	B39
0066-0067	B40
0068-0069	B41
006A	A4
006B	B42
006C-006D	B43
006E	B50
006F	B29
0070-0073	B24
0074-0075	B25
0076-0078	B22
0079-007A	B21
007B	B44
007C	E7
007D	B45
007E-007F	B23
0080-00FF	SEE FLOATING POINT VARIABLE LIST AT END.
0100-01FF	6502 STACK
0200-0201	P10
0202-0203	P14
0204-0205	P15
0206-0207	P16
0208-0209	P17
020A-020B	P18
020C-020D	P19
020E-020F	P20
0210-0215	P21
0216-0217	P13
0218-0219	P4,H26
021A-021B	P6
021C-0221	P8
0222-0223	P11
0224-0225	P12
0226-0227	P5,H27
0228-0229	P7
022A	P9
022B	E8
022C	P9
022D	P28
022E	P9
022F	P22
0230-0231	P23
0232	H23 → 32
0233	S14
0234	J5
0235	J6
0236-0239	S8
023A	H18

023B	H19
023C-023D	H20
023E	H23
023F	H30
0240	N8
0241	N9
0242-0243	N10
0244	N11
0245	S9
0246	C2
0247-026E	B51
026F	P24
0270-0277	J3
0278-027B	J1,J7,J8
027C-0283	J4
0284-0287	J2,J9
0288	S2
0289	D14
028A	D10
028B-028F	S10
0290-0292	B4
0293	B49
0294-0295	B52
0296-029B	B53
029C	S5
029D	B32
029E	B48
029F	B31
02A0	B28
02A1	B47
02A2	B26
02A3-02B1	B13
02B2-02B5	B14
02B6	E9
02B7	B18
02B8-02BA	B46
02BB	B9
02BC	B20
02BD	S1
02BE	E6
02BF	B16
02C0-02C3	B7,P27
02C4-02C8	B8,P27
02C9-02E3	S11
02E4	A5
02E5-02E6	A2
02E7-02E8	A1
02E9	S15
02EA-02ED	G11
02EE-02EF	D1
02F0	B1
02F1	E2
02F2	E1
02F3	P25
02F4	P26
02F5-02F9	S12
02FA	B55
02FB	B54
02FC	E3
02FD	B17

02FE	B27
02FF	E4
0300	H1,H2
0301	H3
0302	H4
0303	H5
0304-0305	H6
0306	H7
0307	S3
0308-0309	H8
030A-030B	H9
030C-030D	D3
030E	D4
030F	D8
0310-0311	D3
0312-0313	D5
0314	S4
0315	D6
0316	D7
0317	D2,H25
0318	H28
0319	H29
031A-033F	G12
0340	G1,G2 (IOCB #0)
0341	G3
0342	G4
0343	G5
0344-0345	G6
0346-0347	G7
0348-0349	G8
034A-034B	G9
034C-034F	G10
0350-035F	G2-G10 (IOCB #1)
0360-036F	G2-G10 (IOCB #2)
0370-037F	G2-G10 (IOCB #3)
0380-038F	G2-G10 (IOCB #4)
0390-039F	G2-G10 (IOCB #5)
03A0-03AF	G2-G10 (IOCB #6)
03B0-03BF	G2-G10 (IOCB #7)
03C0-03E7	F1
03E8-03FC	S13
03FD-047F	D9
0480-06FF	R2

FLOATING POINT PACKAGE VARIABLES

00D4-00D9	M1
00DA-00DF	M2
00E0-00E5	M3
00E6-00EB	M4
00EC	M5
00ED	M6
00EE	M7
00EF	M8
00F0	M9
00F1	M10
00F2	M11

00F3-00F4	M12
00F5-00F6	M13
00F7-00F8	M14
00F9-00FA	M15
00FB	M24
00FC-00FD	M16
00FE-00FF	M17
057E	M18
057F	M19
0580-05FF	M20
05E0-05E5	M21
05E6-05EB	M22
05EC-05F1	M23

4.6 Memory dynamics

The free memory region, as discussed in section 4.1.7, is the area between the end of the boot region and the start of the screen region, and as such, its limits are variable. The bottom of the free region is defined by the content of the variable MEMLO [02E7], and the top of the region is defined by the content of the variable MEMTOP [02E5]. The conditions which cause the setup or alteration of these variables are now discussed.

4.6.1 System initialization process

When the system is powered-up, the extent of the lowest block of contiguous RAM is determined and the limits are saved. The Screen Editor is then opened, thus setting a new (and lower) value in MEMTOP. Then, as discussed in section 7.2, disk or cassette booted software might be brought into memory, which would probably set a new (and higher) value in MEMLO. When the application program finally gets control, MEMLO and MEMTOP will define the maximum amount of free memory available at that time; however, that amount may later decrease further, as described in the next paragraph.

4.6.2 Changing screen modes

The user may, at any time, command the Display handler to change screen modes. In most cases this will involve a change in the memory required for the display list and display data, and hence, will change the value of MEMTOP. Appendix H indicates the amount of memory required for each of the screen modes.

In order to allow the user to protect the portion of free memory space that he is using from being overwritten as a result of a screen mode change, the variable APPMHI [000E] is interpreted by the Display handler as containing the address below which MEMTOP may not extend. If, as a result of a screen mode change, the Display handler determines that the screen memory would extend below APPMHI, then the screen is setup for mode 0, MEMTOP is updated and an error status is returned to the user; otherwise the desired mode change is effected and MEMTOP is updated.

5. I/O subsystem

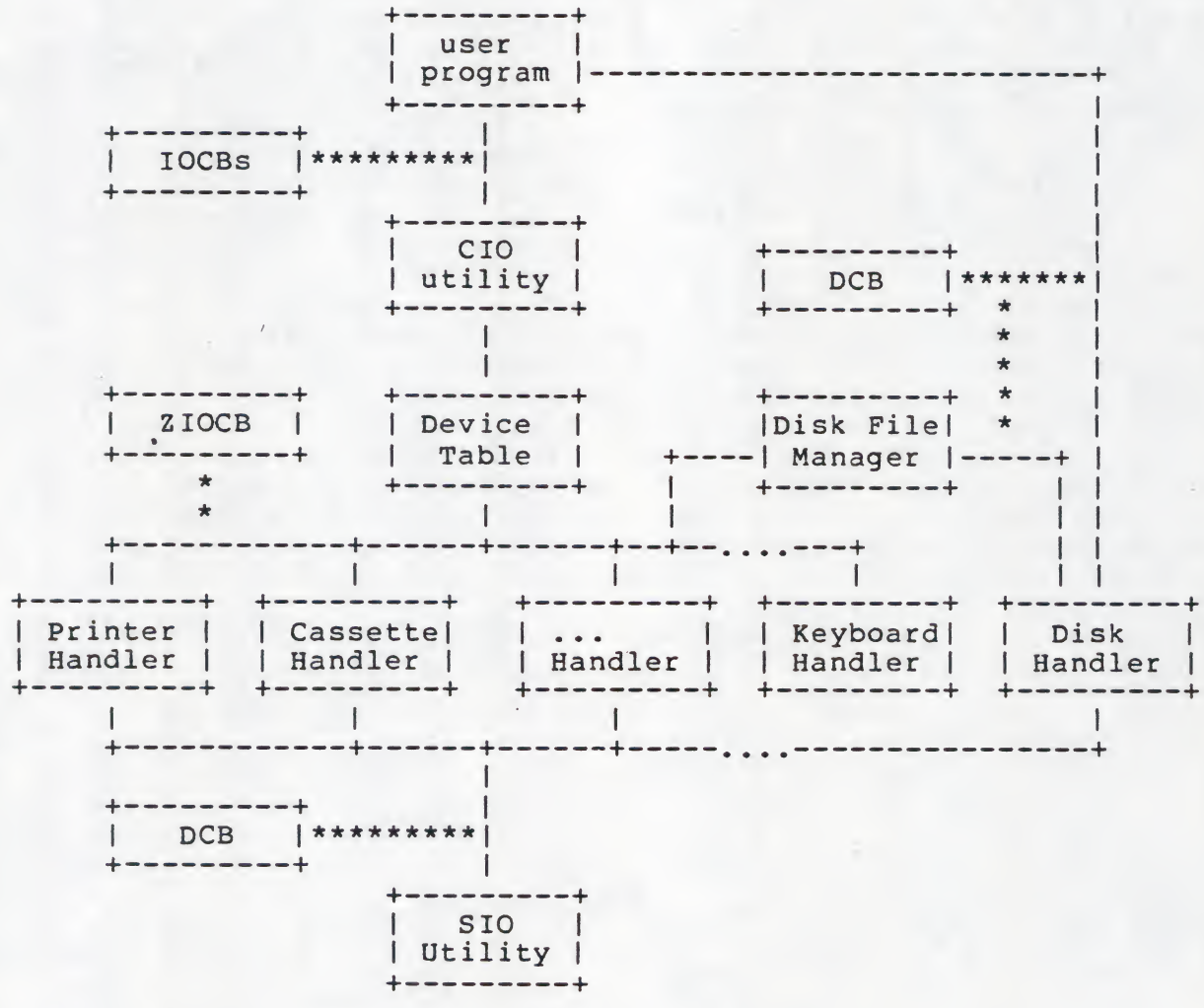
5.1 Overview

This section discusses the I/O subsystem of the operating system. The I/O subsystem is a collection of routines which allows the user to access peripheral and local devices at a number of different levels, all higher than that of accessing the device hardware registers directly. The routine of interest to most users is CIO (Central I/O utility), which provides the highest level, device independent access to devices. The next level down would be communication with the device handlers, followed by use of the SIO (Serial I/O bus utility) routine, which is the bottom level general I/O routine in the O.S. Any lower level access to a device would involve the direct reading and writing of the hardware registers associated with the device.

The basic unit of input/output is the data byte, which can contain either "binary" (non-text) information or encoded text information. The text encoding scheme supported by the O.S. is called ATASCII, the name of which is derived from the words 'ATARI ASCII'. Most ATASCII codes are the same as ASCII, with the primary deviations being the control codes. Appendix D shows the ATASCII character set, and Appendices E, F and G show device specific implementations for the display, keyboard and printer.

The structure of the I/O subsystem is shown on the following page.

I/O SUBSYSTEM FLOW DIAGRAM



Where: ---- shows a control path.
**** shows the data structure required for a path.

Note the following:

1. The Keyboard/Display/Screen Editor handlers don't use SIO.
2. The Disk handler is not callable directly from CIO.
3. The DCB is shown twice in the diagram.

5.2 Central I/O Utility (CIO)

The Central I/O Utility (CIO) provides the user with a single interface with which to access all of the system peripheral devices, in a device independent manner. The minimum unit of data transfer is the data byte, with multiple byte transfers also supported. All I/O operations are performed on a "return to user when complete" basis; there is no way to initiate concurrent "overlapped" I/O processes.

I/O is organized by "files", where a file is a sequential collection of data bytes. A file may or may not contain textual data and it may or may not be organized by "records", where a record is a contiguous group of bytes terminated by an EOL (End of Line) character. Some files are synonymous with a device (as with the printer and the Screen Editor), while other devices may contain a multiplicity of files, each with a unique name (as with the floppy disk).

CIO will allow the user to access up to eight independent device/files at one time; there being that many I/O Control Blocks (IOCBs) in the system. Each of the IOCBs may be assigned to control any desired device/file, as there are no preferred assignments, except that IOCB #0 is assigned to the Screen Editor at power-up and RESET.

In order to access a peripheral, the user must first setup an IOCB for the OPEN command, which supplies the system name for the device to be accessed (e.g. 'K:' for the keyboad, 'P:' for the printer, 'D:STARS' for a disk file named 'STARS', etc.). The user then calls CIO, telling it which IOCB to use to find the OPEN information. CIO attempts to find the specified device/file and returns a status byte indicating the success of the search. If the specified device/file can be found by CIO, then CIO stores control information in the IOCB and that IOCB is now used for as long as that file is OPEN.

Once a file is OPEN, it can then be accessed using data read or data write types of commands; in general, reading may proceed until there is no more data to read (End of File) and writing may proceed until there is no more medium to store data on (End of Medium), although neither reading nor writing need proceed to that point. The reading and writing of data generally occurs into and out of user supplied data buffers (although a special case allowing single byte transfers using the 6502 A register is provided).

When there are no more accesses to be performed on an OPEN device/file, the CLOSE operation is performed by the user. This accomplishes two functions: 1) it terminates and makes permanent an output file (essential for disk and cassette) and 2) it releases that IOCB to be used for another I/O operation.

5.2.1 CIO Design Philosophy

The CIO utility was designed specifically to meet the following design criteria.

The transfer of data is device independent.

Byte-at-a-time, multiple byte and record aligned accesses are supported.

Multiple device/files can be accessed concurrently.

Error handling is largely device independent.

New device handlers may be added without altering the system ROM.

DEVICE INDEPENDENCE

CIO provides device independence by having a single entry point for all devices (and for all operations) and by having a device independent calling sequence. Once a device/file is OPENed, data transfers occur with no regard to the actual device involved. Uniform rules for handling byte and record oriented data transfers allow the actual device storage block sizes to be transparent to the user.

DATA ACCESS METHODS

Two file access methods are supported by CIO: byte aligned and record aligned.

Byte aligned accesses allow the user to treat the device/file as a sequential byte stream; any number of bytes may be read or written and the following operation will continue where the prior one left off. Records are of no consequence in this mode, and reads or writes may encompass multiple records if desired.

Record aligned accesses allow the user to deal with the data stream at a higher level, that of the data record or "line of text". Each and every write operation creates a single record (by definition), and each read operation assures that the following read operation will start at the beginning of a record. Record aligned accesses may not deal with portions of more than one record at a time. Record aligned accesses are useful only with text data or with binary data guaranteed not to contain the EOL character ($9B) as data.

Note that any file may be accessed using the byte aligned access method, regardless of how the file was created. But not all files may be successfully read using record aligned accesses; the file must contain EOL characters at the end of each record and at no other place.

MULTIPLE DEVICE/FILE CONCURRENCY

Up to eight device/files may be accessed concurrently using CIO, each operating independently of the others.

UNIFIED ERROR HANDLING

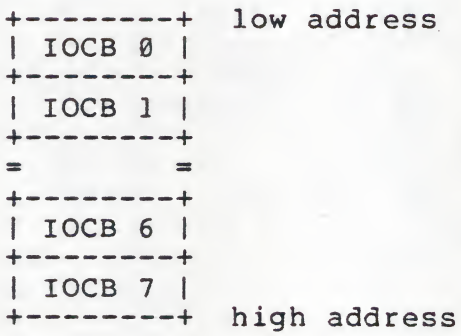
All error detection and recovery occurs within the CIO subsystem and the status information that reaches the user is in the form of a status byte for each device/file. As much as possible, error codes are device independent (see Appendix B).

DEVICE EXPANSION

Devices are known by one character names such as 'K' or 'P', and a number of device handlers are part of the resident system ROM. However, additional device handlers may be added to the system using the RAM resident Device Table; this is normally done at power-up time as with the disk boot process, but may be done at any point in time.

5.2.2 CIO calling mechanism

The primary element in performaing I/O using CIO is an Input/Output Control Block (IOCB). There are eight IOCBs in the system, arranged linearly in RAM as shown below.



One IOCB is required for each OPEN device/file and any IOCB may be used to control any device/file; although IOCB 0 is normally assigned to the Screen Editor (E:). A typical I/O operation is performed by having the user: 1) insert appropriate parameters into an IOCB of his chosing, 2) put the IOCB number times 16 into the 6502 X register and 3) JSR to the CIO entry point CIOV [E456]. CIO will return to the user when the operation is complete or if an error was encountered; the status of the operation will be in the IOCB used as well as in the 6502 Y register. In some cases a data byte will be in the 6502 A register. The X register will remain unchanged for all operations and conditions. An example is shown below:

```
IOCB2X = $20              ; INDEX FOR IOCB #2.

         LDX      #IOCB2X
         JSR      CIOV
         CPY      #0
         BMI      ERROR
```

Each IOCB is sixteen bytes long, in which some bytes are user alterable and some are for use by CIO and/or the device handlers. Each of the IOCB bytes will now be described, and the system equate file name and memory address for each will be given.

HANDLER I.D. -- ICHID [0340]

The handler I.D. is an index into the system Device Table (see section 9.1) and is not user alterable. This byte is set by CIO as the result of an OPEN command and is left unchanged until the device/file is CLOSEd, at which time CIO will set the byte to $FF.

DEVICE NUMBER -- ICDNO [0341]

The device number is provided by CIO as the result of an OPEN command and is not user alterable. This byte is used to distinguish between multiple devices of the same type, such as 'D1:' and 'D2:'.

COMMAND BYTE -- ICCMD [0342]

The command byte is set by the user and tells CIO which of its repertoire of commands is to be performed. The commands and their command byte values will be detailed in section 5.2.3. This byte is not altered by CIO.

STATUS -- ICSTA [0343]

The status byte is used by CIO to convey operation status to the user; it is updated as a result of each and every CIO call. The most significant (sign) bit is a one for error conditions and zero for non-error conditions, and the remaining bits represent an error number. See Appendix B for a list of status codes.

BUFFER ADDRESS -- ICBAL [0344] & ICBAH [0345]

This two byte pointer is set by the user and is not altered by CIO. The pointer contains the address of the beginning (low address) of a buffer which is used to: 1) contain data for read and write operations and 2) contain the device/filename specification for the OPEN command. The pointer may be altered at any time by the user.

PUT ADDRESS -- ICPTL [0346] & ICPTH [0347]

This two byte pointer to the handler's PUT CHARACTER entry point (- 1) is set by CIO at OPEN time; this was provided as an accommodation to the people writing the BASIC cartridge and has no legitimate use in the system. This variable is set to point to CIO's "IOCB not OPEN" routine on CLOSE, power-up and RESET.

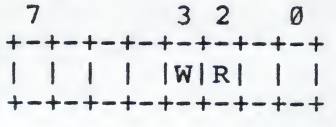
BUFFER LENGTH/BYTE COUNT -- ICBLL [0348] & ICBLH [0349]

This two byte count is set by the user to indicate the size of the data buffer pointed to by ICBAL and ICBAH for read and write operations; it is not required for OPEN. After each read or write operation, CIO will set this parameter to the number of bytes actually transferred into or out of the data buffer. For record aligned accessed, the record length may well be less than the buffer length. Also an end of file condition or an error may cause the byte count to be less than the buffer length.

AUXILLIARY INFORMATION -- ICAX1 [034A] & ICAX2 [034B]

These two bytes are set by the user and contain information which is used by the OPEN command process and/or is device dependent.

For OPEN, two bits of ICAX1 are always used to specify the OPEN direction as shown below, where R is set to 1 for input (read) enable and W is set to 1 for output (write) enable.



ICAX1 is not altered by CIO and should not be altered by the user once the device/file is OPEN.

The remaining bits of ICAX1 and all of ICAX2 contain only device dependent data and are explained in section 5.3.

REMAINING BYTES (ICAX3-ICAX6)

The four remaining bytes are reserved for use by the handler processing the I/O command for CIO. There is no fixed use for these bytes and they are not user alterable except as specified by the particular device descriptions in section 5.3. These bytes will be referred to as ICAX3, ICAX4, ICAX5 and ICAX6, although there are no equates for those names in the O.S. equate file.

5.2.3 CIO functions

There are eight basic functions that are supported by all of the system handlers, subject to restrictions based upon the direction of data transfer (e.g. one cannot read data from the printer). The basic functions are: OPEN, CLOSE, GET CHARACTERS, PUT CHARACTERS, GET RECORD, PUT RECORD, GET STATUS and SPECIAL. Other, device specific, commands are also supported by CIO and are described in section 5.3.

OPEN -- Assign device/filename to IOCB and ready for access.

Before a device/file may be accessed, it must be OPENed; this process links a specific IOCB to the appropriate device handler, initializes the device/file, initializes an CIO control variables, and passes device specific options to the device handler.

The following IOCB parameters are set by the user prior to calling CIO for an OPEN operation:

COMMAND BYTE = $03

BUFFER ADDRESS = pointer to a device/filename specification (see section 5.2.4).

AUX1 = OPEN direction bits, plus device dependent information.

AUX2 = device dependent information.

After an OPEN operation, CIO will have altered the following IOCB parameters:

HANDLER I.D. = index to the system Device Table; this is used only by CIO and must not be altered by the user.

DEVICE NUMBER = device number taken from the device/ filename specification and must not be altered by the user.

STATUS = result of OPEN operation; see Appendix B for a list of the possible status codes. In general, a negative status will indicate a failure to OPEN properly.

PUT ADDRESS = pointer to the PUT CHARACTERS routine for the device handler just OPENed. *** It is recommended that this pointer not be used ***

CLOSE -- Terminate access to device/file and release IOCB.

After the user is through accessing a given device/file, the CLOSE command is issued. This process completes any pending

data writes, goes to the device handler for any device specific actions and then releases the IOCB.

The following IOCB parameter is set by the user prior to calling CIO:

COMMAND BYTE = $0C

The following IOCB parameters are altered by CIO as a result of the CLOSE operation:

HANDLER I.D. = $FF

STATUS = CLOSE status.

PUT ADDRESS = pointer to "IOCB not OPEN" routine.

GET CHARACTERS -- Read n characters (byte aligned access).

The specified number of characters are read from the device/file to the user supplied buffer. EOL characters have no termination features when using this function; there may be no EOL, or many EOLs, in the buffer after operation completion. There is a special case provided that passes a single byte of data in the 6502 A register when the buffer length is set to zero.

The following IOCB parameters are set by the user prior to calling CIO:

COMMAND BYTE = $07

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = number of bytes to read; if this is zero, the data will be returned in the 6502 A register only.

The following IOCB parameters are altered by CIO as a result of the GET CHARACTERS operation:

STATUS = result of GET CHARACTERS operation.

BYTE COUNT/BUFFER LENGTH = number of bytes read to the buffer. The BYTE COUNT will always equal the BUFFER LENGTH except when an error or an end-of-file condition occurs.

PUT CHARACTERS -- Write n characters (byte aligned access).

The specified number of characters are written from the user supplied buffer to the device/file. EOL characters have no buffer terminating properties, although they have their standard meaning to the device/file receiving them; no EOLs are generated by CIO. There is a special case that allows a single character

to be passed to CIO in the 6502 A register if the buffer length is zero.

The following IOCB parameters are set by the user prior to initiating the PUT CHARACTERS operation:

COMMAND BYTE = $0B

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = number of bytes of data in buffer.

The following IOCB parameter is altered by CIO as a result of the PUT CHARACTERS operation:

STATUS = result of PUT CHARACTERS operation.

GET RECORD -- Read up to n characters (record aligned access).

Characters are read from the device/file to the user supplied buffer until either the buffer is full or an EOL character is read and put into the buffer. If the buffer fills before an EOL is read, CIO continues reading characters from the device/file until an EOL is read, then puts an EOL at the end of the buffer, and sets the status to indicated that a truncated record was read.

The following IOCB parameters are set by the user prior to calling CIO:

COMMAND BYTE = $05

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = maximum number of bytes to read.

The following IOCB parameters are altered by CIO as a result of the GET RECORD operation:

STATUS = result of GET RECORD operation.

BYTE COUNT/BUFFER LENGTH = number of bytes read to data buffer; this may be less than the maximum buffer length.

PUT RECORD -- Write up to n characters (record aligned access).

Characters are written from the user supplied buffer to the device/file until either the buffer is empty or an EOL character is written. If the buffer is emptied without writing an EOL character to the device/file, then CIO will send an EOL after the last user supplied character.

The following IOCB parameters are set by the user prior to calling CIO:

COMMAND BYTE = $09

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = maximum number of bytes in buffer.

The following IOCB parameter is altered by CIO as a result of the PUT RECORD operation:

STATUS = result of PUT RECORD operation.

GET STATUS -- Return device dependent status bytes

The device controller is sent a STATUS command, and the controller returns four bytes of status information which are stored in DVSTAT [02EA]. See the subsections of 5.3 for the status information returned by each device.

The following IOCB parameters are set by the user prior to calling CIO:

COMMAND BYTE = $0D

BUFFER ADDRESS = pointer to a device/filename specification (see section 5.2.4) if the IOCB is not already OPEN; see the discussion of the implied OPEN option below.

After a GET STATUS operation, CIO will have altered the following parameters:

STATUS = result of GET STATUS operation; see Appendix B for a list of the possible status codes.

DVSTAT = the four byte response from the device controller.

SPECIAL -- Special function

Any COMMAND BYTE value greater than $0D is treated by CIO as a special case. Since CIO does not know what the function is, CIO transfers control to the device handler for complete processing of the operation.

The following IOCB parameters are set by the user prior to calling CIO:

COMMAND BYTE > $0D

BUFFER ADDRESS = pointer to a device/filename specification (see section 5.2.4) if the IOCB is not already OPEN; see

the discussion of the implied OPEN option below.

Other IOCB bytes may be setup, depending upon the specific SPECIAL command being performed.

After a SPECIAL operation, CIO will have altered the following parameters:

STATUS = result of SPECIAL operation; see Appendix B for a list of the possible status codes.

Other bytes may be altered, depending upon the specific SPECIAL command.

The device specific sections in 5.3 will detail the individual SPECIAL commands supported by the system.

Implied OPEN option

The GET STATUS and SPECIAL commands are treated specially by CIO; they may use an already OPEN IOCB to initiate the process or they may use an unOPENed IOCB. If the IOCB is unOPENed, then the BUFFER ADDRESS must contain a pointer to a device/filename specification, just as for the OPEN command; CIO will then OPEN that IOCB, perform the specified command and then CLOSE the IOCB again.

5.2.4 Device/filename specification

As part of the OPEN command, the IOCB buffer address parameter points to a device/filename specification, which is a string of ATASCII characters in the following format:

```
<specification> ::= <device>[<number>]:[<filename>]<eol>

<device> ::= C|D|E|K|P|R|S
<number> ::= 1|2|3|4
<filename> has device dependent characteristics.
<eol> ::= $9B
```

The following devices are supported at this writing:

```
C = Cassette drive
D1 through D4 = Floppy diskette drives *
E = Screen Editor
K = Keyboard
P = 40 column printer
P2 = 80 column printer *
R1 through R4 = RS-232 interfaces *
S = Screen display
```

Devices flagged by asterisks ('*') are supported by non-resident handlers.

If <number> is not specified, it is assumed to be 1.

The following examples show valid device/filename specifications:

```
C:              Cassette
D2:BDAT         File "BDAT" on disk drive #2
D:HOLD          File "HOLD" on disk drive #1
K:              Keyboard
```

5.2.5 I/O example

The example provided in this section illustrates a simple example of an I/O operation using the CIO routine.

```
; This code segment illustrates the simple example of reading
; text lines (records) from a disk file named "TESTER" on disk
; drive #1.  All symbols used are equated within the program
; although many of the symbols are in the O.S. equate file.

; The program performs the following steps:
;
;     1. OPENs the file 'D1:TESTER' using IOCB #3.
;     2. Reads records until an error or EOF is reached.
;     3. CLOSEs the file.

; I/O EQUATES

EOL=    $9B                     ; END OF LINE CHARACTER.
IOCB3=  $30                     ; IOCB #3 OFFSET (FROM IOCB #0).

ICHID=  $0340                   ; (HANDLER I.D. -- SET BY CIO).
ICDNO=  ICHID+1                 ; (DEVICE # -- SET BY CIO).
ICCOM=  ICDNO+1                 ; COMMAND BYTE.
ICSTA=  ICCOM+1                 ; STATUS BYTE -- SET BY CIO.
ICBAL=  ICSTA+1                 ; BUFFER ADDRESS (LOW).
ICBAH=  ICBAL+1                 ; BUFFER ADDRESS (HIGH).
ICPTL=  ICBAH+1
ICPTH=  ICPTL+1
ICBLL=  ICPTH+1                 ; BUFFER LENGTH (LOW).
ICBLH=  ICBLL+1                 ; BUFFER LENGTH (HIGH).
ICAX1=  ICBLH+1                 ; AUX 1.
ICAX2=  ICAX1+1                 ; AUX 2.

OPEN=   $03                     ; OPEN COMMAND.
GETREC= $05                     ; GET RECORD COMMAND.
CLOSE=  $0C                     ; CLOSE COMMAND.

OREAD=  $04                     ; OPEN DIRECTION = READ.
OWRIT=  $08                     ; OPEN DIRECTION = WRITE.

EOF=    $88                     ; END OF FILE STATUS VALUE.

CIOV=   $E456                   ; CIO ENTRY VECTOR ADDRESS.


;
; FIRST INITIALIZE THE IOCB FOR FILE "OPEN".
;
        LDX     #IOCB3          ; SETUP TO ACCESS IOCB #3.

        LDA     #OPEN           ; SETUP OPEN COMMAND.
        STA     ICCOM,X

        LDA     #NAME           ; SETUP BUFFER POINTER TO ...
        STA     ICBAL,X         ; ... POINT TO FILENAME.
        LDA     #NAME/256
```

```
        STA     ICBAH,X

        LDA     #OREAD          ; SETUP FOR OPEN READ.
        STA     ICAX1,X

        LDA     #0              ; CLEAR AUX 2.
        STA     ICAX2,X

;
; "OPEN" THE FILE.
;

        JSR     CIOV            ; PERFORM "OPEN" OPERATION.
        CPY     #0              ; SEE IF EVERYTHING WENT O.K.
        BPL     TP10            ; YES -- STATUS WAS POSITIVE.

        JMP     ERROR           ; NO -- "OPEN" PROBLEM.

;
; SETUP TO READ A RECORD.
;

TP10    LDA     #GETREC         ; SETUP "GET RECORD" COMMAND.
        STA     ICCOM,X

        LDA     #BUFF           ; SETUP DATA BUFFER POINTER.
        STA     ICBAL,X
        LDA     #BUFF/256
        STA     ICBAH,X

;
; READ RECORDS.
;

LOOP    LDA     #BUFFSZ         ; SETUP MAX RECORD SIZE ...
        STA     ICBLL,X         ; ... PRIOR TO EVERY READ.
        LDA     #BUFFSZ/256
        STA     ICBLH,X

        JSR     CIOV            ; READ A RECORD.
        CPY     #0              ; SEE IF O.K.
        BMI     TP20            ; NO -- MAY BE END OF FILE.

;
; A RECORD IS NOW IN THE DATA BUFFER "BUFF".  IT IS TERMINATED BY
; AN EOL CHARACTER, AND THE RECORD LENGTH IS IN "ICBLL" & "ICBLH".
; THIS EXAMPLE WILL DO NOTHING WITH THE RECORD JUST READ.
;

        JMP     LOOP            ; READ NEXT RECORD.

;
; NEGATIVE STATUS ON READ -- CHECK FOR END OF FILE.
;

TP20    CPY     #EOF            ; END OF FILE STATUS?
        BNE     ERROR           ; NO -- ERROR.

        LDA     #CLOSE          ; YES -- CLOSE FILE.
        STA     ICCOM,X
```

```
        JSR     CIOV            ; CLOSE THE FILE.
        HLT                     ; *** END OF PROGRAM ***

;
; DATA REGION OF EXAMPLE PROGRAM
;
NAME    .BYTE   "D1:TESTER",EOL
BUFFSZ= 80                      ; 80 CHARACTER RECORD MAX (INCLUDES EOL).
BUFF=   *                       ; READ BUFFER.
*=      *+BUFFSZ
        .END
```

5.3 Device specific information

This section provides device specific information regarding device handlers that interface to CIO.

5.3.1 Keyboard handler (K:)

The Keyboard device is a read only device with a handler that supports the following CIO functions:

OPEN
CLOSE
GET CHARACTERS
GET RECORD
GET STATUS (null function)

The Keyboard handler may produce the following error statuses:

$80 -- BREAK key abort.
$88 -- End-of-file (produced by pressing CTRL-3).

The Keyboard handler is one of the resident handlers, and therefore has a set of device vectors starting at location E420, as described further in section 5.4.1.

The keyboard can produce any of the 256 codes in the ATASCII character set as shown in Appendix F. Note that a few of the keyboard keys do not generate data at the Keyboard handler level; these keys are described below:

)|(-- The ATARI key toggles a flag which enables/disables the inversion of bit-7 of each data character read. The Screen Editor editing keys are exempted from such inversion, however.

CAPS - The CAPS key provides three functions:
SHIFT-CAPS -- Alpha caps lock.
CTRL-CAPS -- Alpha CTRL lock.
CAPS -- Alpha unlock.
The system powers-up and RESETs to the Alpha caps lock option.

Some key combinations are defined to be invalid, such as CTRL-4 through CTRL-9, CTRL-0, CTRL-1, CTRL-/ and all key combinations in which the SHIFT and CTRL keys are depressed simultaneously.

The CTRL-3 key generates an EOL character and returns EOF status.

The BREAK key generates an EOL character and returns BREAK status.

CIO function descriptions

The device specific characteristics of the standard CIO functions (described earlier in section 5.2.3) are detailed below:

OPEN

The device name is 'K', and the handler ignores any device number and filename specification, if included.

There are no device dependent option bits in AUX1 or AUX2.

CLOSE

No special handler actions.

GET CHARACTERS and GET RECORD

The handler returns the ATASCII key codes to CIO as they are entered, with no facility for editing.

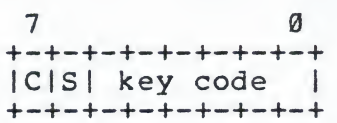
GET STATUS

The handler does nothing but set the status to $01.

Theory of operation.

Everytime a keyboard key is pressed, an IRQ interrupt is generated as discussed in section 6.4 and is vectored to the Keyboard handler's interrupt service routine as shown in section 6.5. The key code for the key pressed is then read and stored in data base variable CH [02FC]; this occurs whether or not there is an active read request to the Keyboard handler, thus effecting a one byte FIFO for keyboard entry. See section 4.5 (E8) for a discussion of the auto-repeat feature.

Whenever there is an active read request for the Keyboard handler, the handler monitors the CH variable for not containing the value $FF (empty state). When CH shows non-empty, the handler takes the key code from CH and sets CH to $FF again. The key code byte obtained from CH is not ATASCII code and has the following form:



Where: C = 1 if the CTRL key is pressed.
S = 1 if the SHIFT key is pressed.
The remaining 6 bits are the hardware key code.

The key code obtained is then converted to ATASCII using the first of the following rules which applies:

1. Ignore the code if the C & S bits are both set.
2. If the C bit is set, process the key as a CTRL code.
3. If the S bit is set, process the key as a SHIFT code.
4. If CTRL lock is in effect, process alpha characters as CTRL codes, all others as lower case.
5. IF SHIFT lock is in effect, process alpha characters as SHIFT codes, all others as lower case.
6. Else, process as lower case character.

Then, if the resultant code is not a Screen Editor control code, and if the video invert flag is set, set bit-7 of the ATASCII code (causes inverse video when displayed).

The keycode to ATASCII conversion table is shown on the next page. See also Appendix F.

KEYCODE TO ATASCII CONVERSION TABLE

Key Code	Key Cap	l.c.	SHIFT	CTRL	Key Code	Key Cap	l.c.	SHIFT	CTRL
00	L	6C	4C	0C	20	,	2C	5B	00
01	J	6A	4A	0A	21	SPACE	20	20	20
02	;	3B	3A	7B	22	.	2E	5D	60
03	--	--	--	--	23	N	6E	4E	0E
04	--	--	--	--	24	--	--	--	--
05	K	6B	4B	0B	25	M	6D	4D	0D
06	+	2B	5C	1E	26	/	2F	3F	--
07	*	2A	5E	1F	27	)|(	--	--	--
08	O	6F	4F	0F	28	R	72	52	12
09	--	--	--	--	29	--	--	--	--
0A	P	70	50	10	2A	E	65	45	05
0B	U	75	55	15	2B	Y	79	59	19
0C	RET	9B	9B	9B	2C	TAB	7F	9F	9E
0D	I	69	49	09	2D	T	74	54	14
0E	-	2D	5F	1C	2E	W	77	57	17
0F	=	3D	7C	1D	2F	Q	71	51	11
10	V	76	56	16	30	9	39	28	--
11	--	--	--	--	31	--	--	--	--
12	C	63	43	03	32	0	30	29	--
13	--	--	--	--	33	7	37	27	--
14	--	--	--	--	34	BACKS	7E	9C	FE
15	B	62	42	02	35	8	38	40	--
16	X	78	58	18	36	<	3C	7D	7D
17	Z	7A	5A	1A	37	>	3E	9D	FF
18	4	34	24	--	38	F	66	46	06
19	--	--	--	--	39	H	68	48	08
1A	3	33	23	9B*	3A	D	64	44	04
1B	6	36	26	--	3B	--	--	--	--
1C	ESC	1B	1B	1B	3C	CAPS	--	--	--
1D	5	35	25	--	3D	G	67	47	07
1E	2	32	22	FD	3E	S	73	53	13
1F	1	31	21	--	3F	A	61	41	01

* CTRL-3 returns EOF status.

The inverse of this table (ATASCII to keystroke) is given in Appendix F.

5.3.2 Display handler (S:)

The Display device is a read/write device with a handler that supports the following CIO functions:

OPEN
CLOSE
GET CHARACTERS
GET RECORD
PUT CHARACTERS
PUT RECORD
GET STATUS (null function)

DRAW
FILL

The Display handler may produce the following error statuses:

$84 -- Invalid special command.
$8D -- Cursor out of range.
$91 -- Screen mode > 11.
$93 -- Not enough memory for screen mode selected.

The Display handler is one of the resident handlers, and therefore has a set of device vectors starting at location E410, as described further in section 5.4.1.

Screen modes

The display screen may be operated in any of 20 configurations (modes 1 through 8, with or without split screen, plus modes 0 and 9 through 11 without split screen). Mode 0 is the text displaying mode and modes 1 through 11 are all different graphics modes (although modes 2 and 3 do display a subset of the ATASCII character set). Modes 9 through 11 require a GTIA chip to be installed in place of the standard CTIA chip.

TEXT MODE (mode 0)

In text mode the screen is physically comprised of 24 lines of 40 characters per line; however, the display area is limited by program alterable left and right margins which default to 2 and 39 (of a possible 0 and 39).

A program controllable cursor shows the destination of the next character to be output. The cursor is visible as the inverted video representation of the current character at the destination position.

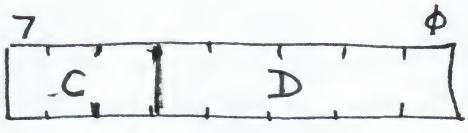
The text screen data is organized internally as variable length logical lines; when the screen is cleared, the internal representation is 24 empty lines. As text is sent to the screen, each EOL marks the end of a logical line; or if more than 3 physical lines of text are sent, a logical line will be formed every 3 physical lines. The number of physical lines used to comprise a logical line (1 to 3) is always the minimum required to hold the data for that logical line.

The text screen "scrolls" upward whenever a text line at the bottom row of the screen extends past the right margin or a text

TEXT MODES 1 & 2

In ~~the~~ text modes 1 and 2 the screen is physically comprised of either 24 lines of 20 characters (mode 1) or 12 lines of 20 characters (mode 2). The left and right margins are of no consequence in these modes and there is no visible cursor. ~~Data for~~ There are no logical lines associated with the data and in all regards these modes are treated as graphics modes by the handler.

Data going to or coming from the screen is in the form shown below:



where: C ~~is the~~ color/data set select field

0 = green (PF1) '!' - '?' or '♥' - '→'
1 = gold (PF0) '!' - '?' or '♥' - '→'
2 = gold (PF0) '@' - '_' or '♦' - '▶'
3 = green (PF1) '@' - '_' or '♦' - '▶'
4 = red (PF3) '!' - '?' or '♥' - '→'
5 = blue (PF2) '!' - '?' or '♥' - '→'
6 = blue (PF2) '@' - '_' or '♦' - '▶'
7 = red (PF3) '@' - '_' or '♦' - '▶'

C value	color (default)	color register (See Appendix H)	char set CHBAS = $E0	char set CHBAS = $E2

D is a 5 bit truncated ~~ASCII~~ ATASCII code which selects the specific character within the set selected by the C field. See Appendix E for the graphics representations of the characters.

CHBAS = as per blurb in Advanced techniques.

line at the bottom row is terminated by an EOL. Scrolling has the effect of removing the entire logical line that starts at the top of the screen and then moving all subsequent lines upward to fill in the void. The cursor will also move upward if the logical line deleted exceeeds one physical line.

All data going to or coming from the text screen is represented in 8 bit ATASCII code as shown in Appendix E.

GRAPHICS MODES (modes 1 through 11)

The screen has varying physical characteristics for each of the graphics modes as shown in Appendix H. Depending upon the mode, a 1 to 16 color selection is available for each pixel and the screen size varies from 20 by 12 (lowest resolution) to 320 by 192 (highest resolution) pixels.

There is no visible cursor for the graphics mode output.

Data going to or coming from the graphics screen is represented as 1 to 8 bit codes as shown in Appendix H and in the GET/PUT diagrams following.

SPLIT SCREEN CONFIGURATIONS

In split screen configurations, the bottom of the screen is reserved for four lines of mode 0 text. The text region is controlled by the Screen Editor (described in section 5.3.3), and the graphics region is controlled by the Display handler. Two cursors are maintained in this configuration so that the screen segments may be managed independently.

In order to operate in split screen mode, the Screen Editor must first be OPENed and then the Display handler must be OPENed using a separate IOCB (with the split screen option bit set in AUX1).

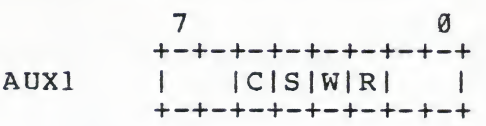
CIO function descriptions

The device specific characteristics of the standard CIO functions (described earlier in section 5.2.3) are detailed below:

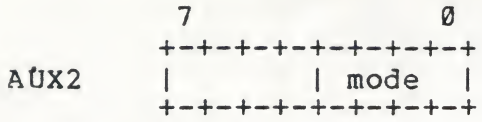
OPEN

The device name is 'S', and the handler ignores any device number and filename specification, if included.

The handler supports the following options:



Where: C = 1 indicates to inhibit screen clear on OPEN.
S = 1 indicates to setup a split screen configuration (for modes 1 through 8 only).
R & W are the direction bits (read & write).



Where: mode is the screen mode (0 through 11).

Note: If the screen mode selected is 0, then the AUX1 options are ignored.

Because the Display handler dynamically allocates high address memory for use in generating the screen display, and because different amounts of memory are needed for the different screen modes, the Display handler and the user must share memory utilization information. Prior to initiating an OPEN command the variable APPMHI [000E] should contain the highest address of RAM needed by the user; the Screen handler will OPEN the screen only if no RAM is needed at or below that address.

Upon return from a screen OPEN, the variable MEMTOP [02E5] will contain the address of the last free byte at the end of RAM memory prior to the screen required memory.

As a result of every OPEN command, the following screen variables are altered:

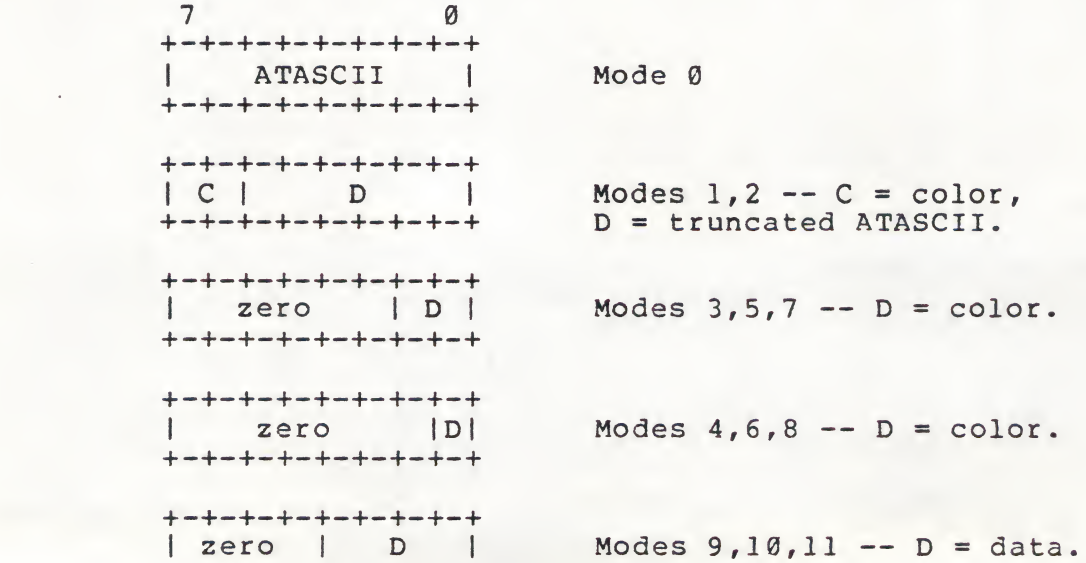
The text cursor is enabled (CRSINH = 0).
The tabs are set to the default settings (2 & 39).
The color registers are set to the default values.

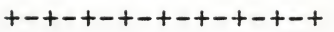
CLOSE

No special handler actions.

GET CHARACTERS and GET RECORD

Returns data in the following screen mode dependent forms, where each byte contains the data for one cursor position (pixel); there is no facility for having the handler return packed graphics data.

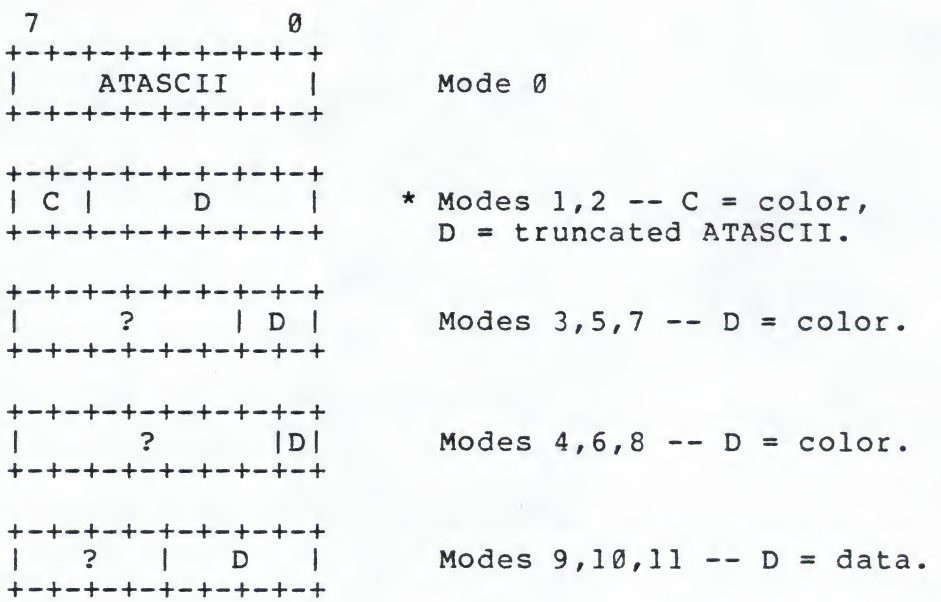




As each data byte is returned, the cursor is moved to the next cursor position. For mode 0, the cursor will stay within the specified margins; for all other modes, the margins are ignored.

PUT CHARACTERS and PUT RECORD

The handler accepts display data in the following screen mode dependent forms; there is no facility for the handler to receive graphics data in packed form.



Note: for all modes, if the output data byte equals $9B (EOL) that byte will be treated as an EOL character; and if the output data byte equals $7D (CLEAR) that byte will be treated as a screen clear character.

* For screen modes 1 and 2, an '[' character ($5B truncated to $1B) with a color select of 2 will have a value of $9B which will be recognized as an EOL.

As each data byte is written, the cursor is moved to the next cursor position. For mode 0, the cursor will stay within the specified margins; for all other modes, the margins are ignored.

While outputting, the Display handler monitors the keyboard to detect the pressing of the CTRL-1 key combination; when this occurs, the handler loops internally until that key combination is pressed again, thus effecting a stop/start function to freeze the screen display. Note that there is no ATASCII code associated with either the CTRL-1 key combination or the start/stop function; the stop/start function may be controlled only from the keyboard (or by altering database variable CH as discussed in section 4.5 E4).

GET STATUS

No handler action except to set the status to $01.

DRAW

This special command draws a simulated "straight" line from the current cursor position to the location specified in ROWCRS [0054] and COLCRS [0055]. The color of the line is taken from the last character processed by the Display handler or Screen Editor. To force the color, store the desired value in ATACHR [02FB]. At the completion of the command, the cursor will be at the location specified by ROWCRS and COLCRS.

The value for the command byte for DRAW is $11.

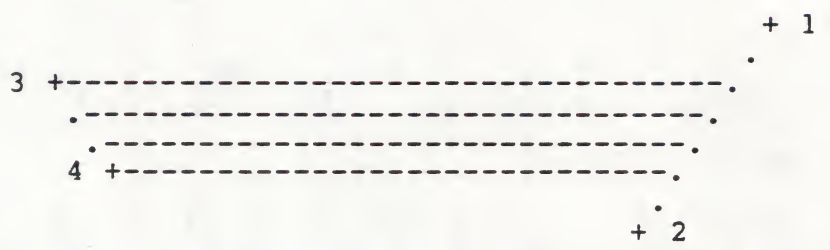
FILL

This special command fills an area of the screen defined by two lines with a specified color. The command is setup the same as in DRAW, but as each point of the line is drawn, the routine scans to the right performing the procedure shown below (in Pascal notation):

```
WHILE PIXEL [ROW,COL] = 0 DO
   BEGIN
      PIXEL [ROW,COL] := FILDAT;
      COL := COL + 1;
      IF COL > RMARGN THEN COL := 0
   END;
```

(no -- graphics right edge!)

An example of a FILL operation is shown below:



Where: '-' represents the fill operation.
'.' are the line points, with '+' for the endpoints.

1 -- set cursor and plot point.
2 -- set cursor and DRAW line.
3 -- set cursor and plot point.
4 -- set fill data value, set cursor and FILL.

FILDAT [02FD] contains the fill data and ROWCRS and COLCRS contain the cursor coordinates of the line endpoint. The value in ATACHR [02FB] will be used to draw the line; ATACHR always contains the last data read or written, so if the steps above are followed exactly, ATACHR will not have to be modified.

The value for the command byte for FILL is $12.

User alterable database variables

Certain functions of the Display handler require the user to examine and/or alter variables in the O.S. database; the

paragraphs that follow describe some of the more commonly used handler variables. There are additional descriptions to be found in section 4.5 B1-55.

CURSOR POSITION

The cursor position for the graphics screen or mode 0 text screen is maintained in two variables: ROWCRS [0054], the display row number, and COLCRS [0055], the display column number. Both numbers range from 0 to the maximum number of rows/columns - 1. The cursor may be set outside of the defined text margins with no ill effect; this region may be read from and written to when the cursor is controlled by the user. The home position (0,0) for both text and graphics is the upper left corner of the screen.

ROWCRS is a single byte, and COLCRS is two bytes with the least significant byte being at the lower address.

When these variables are altered by the user, the screen representation of the cursor will not move until the next I/O operation involving the display is performed.

INHIBIT/ENABLE VISIBLE CURSOR DISPLAY

The user may inhibit the display of the text cursor on the screen by setting the variable CRSINH [02F0] to any non-zero value. Subsequent I/O will not generate a visible cursor.

The user may enable the display of the text cursor by setting CRSINH to zero. Subsequent I/O will then generate a visible cursor.

TEXT MARGINS

As mentioned earlier, the text screen has user alterable left and right margins, which are normally set to 2 and 39 by the O.S. The variable LMARGN [0052] defines the left margin and RMARGN [0053] defines the right margin. The leftmost margin value is 0 and the rightmost margin value is 39.

The margin values inclusively define the useable portion of the screen for all operations in which the user does not explicitly alter the cursor location variables as described prior to this paragraph.

COLOR CONTROL

As part of normal stage 2 VLANK processing (as discussed in Section 6.3.2) the hardware color registers are updated using data from the O.S. database. Shown below are the database variable names, the hardware register names and the function of each register; see Appendix H for the mode dependent uses for the registers.

Database	Hardware	Function
COLOR0	COLPF0	PF0 -- Playfield 0.
COLOR1	COLPF1	PF1 -- Playfield 1.
COLOR2	COLPF2	PF2 -- Playfield 2.

COLOR3	COLPF3	PF3 -- Playfield 3.
COLOR4	COLBK	BAK -- Playfield background.
PCOLR0	COLPM0	PM0 -- Player/missile 0.
PCOLR1	COLPM1	PM1 -- Player/missile 1.
PCOLR2	COLPM2	PM2 -- Player/missile 2.
PCOLR3	COLPM3	PM3 -- Player/missile 3.

Theory of operation

The Display handler automatically sets up all memory resources required to create and maintain the screen display at OPEN time. The screen generation hardware requires that two distinct data areas exist for graphics modes: 1) a display list and 2) a screen data region; a third data area must exist for text modes which defines the screen representation for each of the text characters. The Atari Personal Computer HARDWARE MANUAL must be referenced for a complete understanding of the material that is to follow.

The simplified block diagram below shows the relationships between the memory and hardware registers used to setup a screen display (without player/missile objects) by the O.S.; be aware that the hardware allows for many other possibilites.

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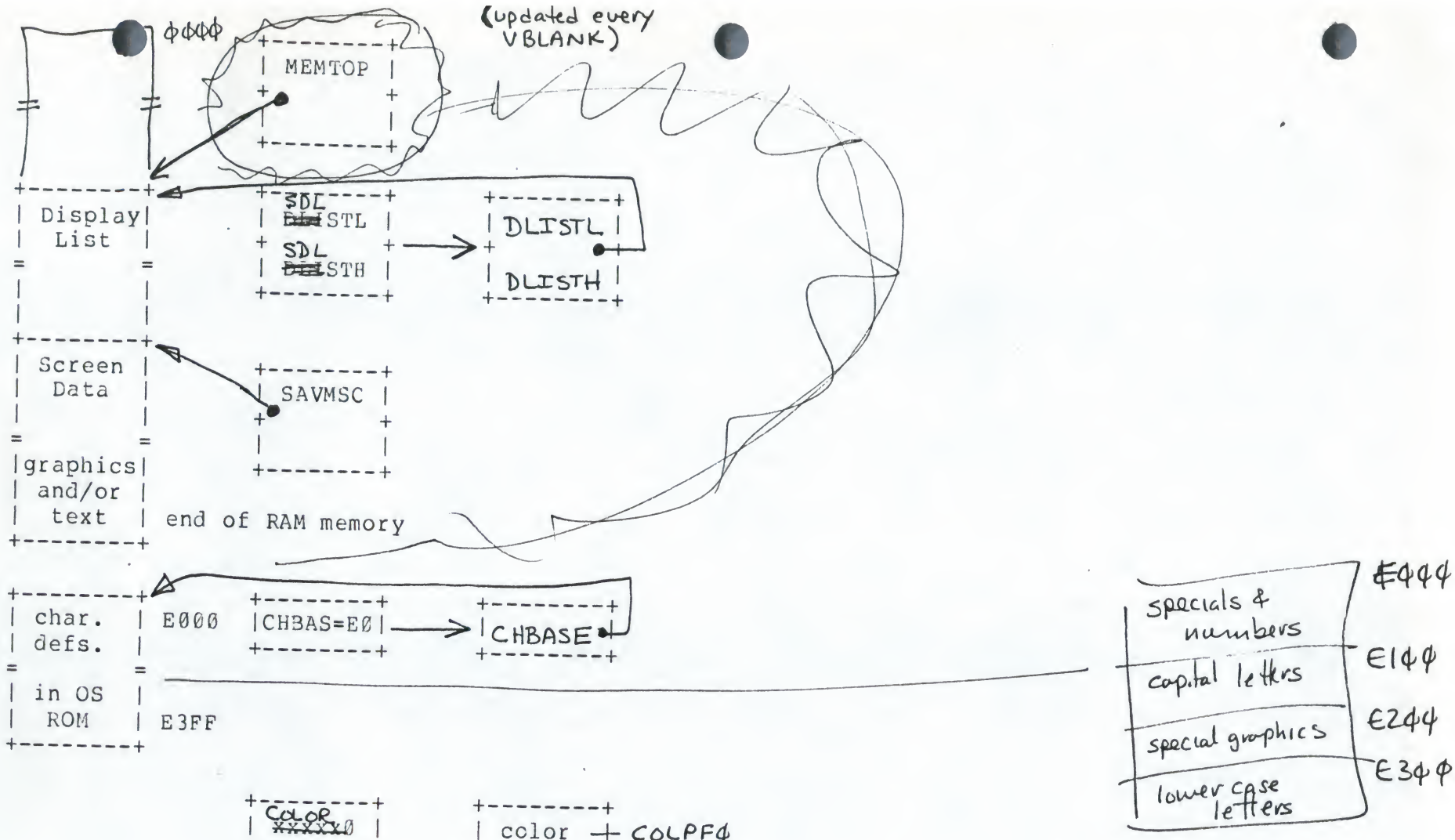
(updated every VBLANK)
ΦΦΦΦ
MEMTOP
Display List
SDLSTL
SDLSTH
DLISTL
DLISTH
Screen Data
SAVMSC
graphics and/or text
end of RAM memory
char. defs.
in OS ROM
E000
CHBAS=EØ
CHBASE
E3FF
specials & numbers
capital letters
special graphics
lower case letters
EΦΦΦ
E1ΦΦ
E24Φ
E3ΦΦ
COLOR0
COLOR1
COLOR2
COLOR3
COLOR4
color regs.
COLPFΦ
COLPF1
COLPF2
COLPF3
COLBK

In the preceding diagram the following relationships are present:

Database variables SDL~~DLI~~STL/SDL~~DLI~~STH contain the address of the current display list; as part of the Stage 1 VBLANK process this address is stored in the hardware display list address registers ~~xxxxx~~ DLISTL and DLISTH.

The display list itself defines the characteristics of the screen to be displayed and points to the memory containing the data to be displayed.

Database variable CHBAS contains the msb of the base address of the character representations for the character data (text modes only). The default value for this variable is $E0, which declares that the character representations start at memory address E000 (the character set provided by the O.S. in ROM). Each character is defined as an 8X8 bit matrix, requiring 8 bytes per character; since a character code contains up to 7 significant bits (set of 128 characters), 1024 bytes are required to define the largest set. The O.S. ROM contains the default set in the region from E000 to E3FF.

Database variables COLOR0 ~~xxxxx~~ through COLOR4 ~~xxxxx~~ contain the current color register assignments; these are also stored in the hardware color registers as part of the Stage 1 VBLANK process, thus providing synchronized color changes. Appendix H provides more information regarding the color registers.

Database variable SAVMSC points to the lowest memory address of the screen data region, which corresponds to the data displayed at the upper left corner of the display.

All character ~~xxxxxxx~~ codes are converted (and vice versa) by the handler from ATASCII to an internal code, as shown below:

ATASCII CODE	INTERNAL CODE
00-1F	40-5F
20-3F	00-1F
40-5F	20-3F
60-7F	60-7F
80-9F	C0-DF
A0-BF	80-9F
C0-DF	A0-BF
E0-FF	E0-FF

The character set in ROM is ~~layed~~ laid out in internal code order. The reason internal code being different from the external code (ATASCII) is based on considerations: 1) ATASCII codes for all but the special graphics were ASCII, specifically the alphabetic, numeric and punctuation character codes ASCII, ~~xxxx~~ 2) in text modes 1 and 2 it was desired that one character set letters, ~~xxxx~~ numbers and punctuation and the other character subset special character graphics characters and 3) the codes for the

age 1 VBLANK process this
ay list address registers

racteristics of the
e memory containing the

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haracter data (text modes
able is $E0, which
ions start at memory
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matrix, requiring 8 — code
contains up to 7
), 1024 bytes are
e O.S. ROM contains the
E3FF.

contain the current color
ored in the hardware
VBLANK process, thus
Appendix H provides more
rs.

lowest memory address of
ds to the data displayed
.

and vice versa,

converted by the handler
., as shown below:

characters

out in internal code order. The reason for the
e external code (ATASCII) is based upon ~~the~~ three
for all but the special graphics were to be similar to
numeric and punctuation characters codes are identical to
2 it was desired that one character subset include capital
ation and the other character subset include lower case letters
racters and 3) the codes for the capital and lower case letters were to
the same set. identical in text modes 1 and 2.

EN command, it first
N IOCB. It then
s specified by database

When the Display Handler receives an OPEN command, it first determines the screen mode from the OPEN IOCB. It then allocates memory from the end of RAM (as specified by database variable ~~xxxxxx~~) downward; first for the screen data and then for the display list. If there is sufficient memory available, the screen data region is cleared, the display list is created and the display list address is stored to the database.

RAMTOP

5.3.3 Screen Editor (E:)

The Screen Editor is a read/write handler that uses the Keyboard handler and the Display handler to provide "line at a time" input with interactive editing functions, as well as formatted output.

The Screen Editor supports the following CIO functions:

OPEN
CLOSE
GET CHARACTERS
GET RECORD
PUT CHARACTERS
PUT RECORD
GET STATUS (null function)

The Screen Editor may produce the following error statuses:

see Keyboard handler and Display handler.

The Screen Editor is one of the resident handlers, and therefore has a set of device vectors starting at location E400, as described further in section 5.4.1.

The Screen Editor may be thought of as a program which reads key data from the Keyboard handler and sends each character to the Display handler for immediate display; and in addition, accepts data from the user to send to the Display handler. In addition, the Screen Editor reads data from the Display handler (not the Keyboard handler) for the user. In fact, the Keyboard handler, Display handler and the Screen Editor are all contained in one monolithic hunk of code, and thus, are even more closely related than indicated.

Most of the behaviors already defined for the Keyboard handler and the Display handler apply to the Screen Editor, so the discussions in this section will pertain to deviations from those behaviors or to additional features that are part of the Screen Editor only. The Screen Handler deals only with text data (screen mode 0) as described in section 5.3.2. A split screen configuration is allowed which is also explained in section 5.3.2.

Whereas the Display handler allows the graphics and text screens to be readable on program demand, the Screen Editor gives the operator at the keyboard the control of what portion of the screen is to be read and when it is to be read. The choice of when is governed by the RETURN key, and the choice of where is governed by the location of the cursor when the RETURN key is pressed. When the RETURN key is pressed, the entire logical line within which the cursor resides is then made available to the calling program. Trailing blanks in a logical line are never returned as data, however. After all of the data in the line has been sent to the caller (this may entail multiple READ CHARACTERS functions if desired), the cursor is positioned to the beginning of the logical line following the one just read.

CIO function descriptions

The device specific characteristics of the standard CIO functions (described earlier in section 5.2.3) are detailed below:

OPEN

The device name is 'E', and the Screen Editor ignores any device number and filename specification, if included.

The Screen Editor supports the following option:

```
             7               0
            +-+-+-+-+-+-+-+-+
     AUX1   |         |W|R| |F|
            +-+-+-+-+-+-+-+-+
```

Where: R & W are the direction bits (read and write).
F = 1 indicates that a "forced read" is desired (see GET CHARACTER and GET RECORD for more information).

CLOSE

No special handler actions.

GET CHARACTER and GET RECORD

Normally the Screen Editor will return data to the caller only when prompted to do so by having the operator at the keyboard press the RETURN key. However, the "forced read" OPEN option, allows a caller to read text data without operator intervention; when a read operation is commanded, the Screen Editor will return data from the start of the logical line in which the text cursor is located and then move the cursor to the beginning of the following logical line. A read of the last logical line on the screen will cause the screen data to scroll.

A special case occurs when characters are output without a terminating EOL and then additional characters are appended to that logical line from the keyboard. When the RETURN key is pressed, only the keyboard entered characters are sent to the caller, unless the cursor has been moved out of and then back into the logical line, in which case all of the logical line will be sent.

PUT CHARACTER and PUT RECORD

The handler accepts ATASCII characters as one character per byte. Sixteen of the 256 ATASCII characters are control codes; the EOL code has universal meaning, but most of the other control codes have special meaning only to a display or print device. The Screen Editor processing of the ATASCII control codes is explained below:

CLEAR ($7D) -- The current display is cleared of all data and the cursor is placed at the home position (upper left corner of the screen).

CURSOR UP ($1C) -- The cursor is moved up by one physical line. The cursor will wrap from the top line of the display to the bottom line.

CURSOR DOWN ($1D) -- The cursor is moved down by one physical line. The cursor will wrap from the bottom line of the display to the top line.

CURSOR LEFT ($1E) -- The cursor is moved left by one column. The cursor will wrap from the left margin of a line to the right margin of the same line.

CURSOR RIGHT ($1F) -- The cursor is moved right by one column. The cursor will wrap from the right margin of a line to the left margin of the same line.

BACKSPACE ($7E) -- The cursor is moved left by one column (but never past the beginning of a logicical line) and the character at that new position is changed to a blank ($20).

SET TAB ($9F) -- A tab point is established at the logical line position at which the cursor is residing. The logical line tab position is not synonymous with the physical line column position since the logical line may be up to 3 physical lines in length. For example, tabs may be set at the 15th, 30th, 45th, 60th and 75th character positions of a logical line as shown below:

```
Ø 2      9         19        29        39  Screen column #.
--L------+---------+---------+---------R   L/R = margins.

xx--------------T--------------T--------   A logical line.
xx------T--------------T--------------T-   x = inaccesible
xx-------------------------------------       columns.
```

Note the effect of the left margin in defining the limits of the logical line.

The handler default tab settings are shown below:

```
Ø 2      9         19        29        39  Screen column #.
--L------+---------+---------+---------R   L/R = margins.

xxT----T-------T-------T-------T-------T   A logical line.
xx-----T-------T-------T-------T-------T   x = inaccesible
xx-----T-------T-------T-------T-------T       columns.
```

CLEAR TAB ($9E) -- The current cursor position within the logical line is cleared from being a tab point. There is no "clear all tab points" facility provided by the handler.

TAB ($7F) -- The cursor is moved to the next tab point in the current logical line, or to the beginning of the next line if no tab point is found. Note that this function will not increase the logical line length to accommodate a tab point outside the current length (e.g. the logical line length is 38 characters and there is a tab point at position 50).

INSERT LINE ($9D) -- The physical line in which the cursor resides, and all physical lines below that line, are moved down by one physical line; the last logical line on the display may be truncated as a result. The blank physical line at the insert point becomes the beginning of a new logical line. A logical line may be split into two logical lines by this process, the

last half of the original logical line begin concatenated with the blank physical line formed at the insert point.

DELETE LINE ($9C) -- The logical line in which the cursor resides is deleted and all data below that line is moved upward to fill the void. Empty logical lines are created at the bottom of the display.

INSERT CHARACTER ($FF) -- The character at the cursor position, and all remaining characters in the logical line, are moved one position to the right and the character at the cursor position is set to blank. The last character of the logical line will be lost when the logical line is full and a character is inserted. The number of physical lines comprising a logical line may increase as a result of this function.

DELETE CHARACTER ($FE) -- The character on which the cursor resides is removed, and the remainder of the logical line to the right of the deleted character is moved to the left by one position. The number of physical lines comprising a logical line may decrease as a result of this function.

ESCAPE ($1B) -- The next non-EOL character following this code is displayed as data, even if it would normally be treated as a control code. The sequence ESC ESC will cause the second ESC character to be displayed.

BELL ($FD) -- An audible tone is generated; the display is not modified.

END OF LINE ($9B) -- In addition to its record termination function, the EOL causes the cursor to advance to the beginning of the next logical line. When the cursor reaches the bottom line of the screen, the receipt of an EOL will cause the screen data to scroll upward by one logical line.

Output start/stop using the CTRL-1 key is processed as explained in section 5.3.2.

GET STATUS

The handler takes no action other than to set the status to $01.

User alterable database variables

See also the Display handler database variable discussion in section 5.3.2.

CURSOR POSITION (split screen)

When in a split screen configuration, ROWCRS and COLCRS are associated with the graphics portion of the display and two other variables, TXTROW [0290] and TXTCOL [0291], are associated with the text window. TXTROW is a single byte, and TXTCOL is two bytes with the least significant byte being at the lower address. Note that the most significant byte of TXTCOL should always be zero.

The home position (0,0) for the text window is the upper left corner of the window.

ENABLE/INHIBIT OF CONTROL CODES IN TEXT

Normally all text mode control codes are operated upon as received, but sometimes it is desireable to have the control codes displayed as if they were data characters. This is done by setting the variable DSPFLG [02FE] to any non-zero value before outputting the data containing control codes. Setting DSPFLG to zero restores normal processing of text control codes.

5.3.4 Cassette handler (C:)

The Cassette device is a read or write device with a handler that supports the following CIO functions:

OPEN
CLOSE
GET CHARACTERS
GET RECORD
PUT CHARACTERS
PUT RECORD
GET STATUS (null function)

The Cassette handler may produce the following error statuses:

$80 -- BREAK key abort.
$84 -- Invalid AUX1 byte on OPEN.
$88 -- End-of-file.
$8A-90 -- SIO error set (see Appendix C).

The Cassette handler is one of the resident handlers, and therefore has a set of device vectors starting at location E440, as described further in section 5.4.1.

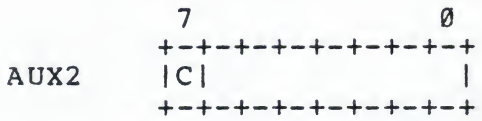
CIO function descriptions

The device specific characteristics of the standard CIO functions (described earlier in section 5.2.3) are detailed below:

OPEN

The device name is 'C', and the handler ignores any device number and filename specification, if included.

The handler supports the following option:



Where: C = 1 indicates that the cassette is to be read/written without stop/start between records (continuous mode).

When the cassette is OPENed for input, a single audible tone is generated, using the keyboard speaker, as a prompt for the operator to verify that the cassette player is setup for reading (power on, Serial Bus cable connected, tape cued to start of file and PLAY button depressed). When the cassette is ready, the operator may press any keyboard key (except BREAK) to initiate tape reading.

When the cassette is OPENed for output, two closely spaced audible tones are generated, using the keyboard speaker, as a prompt for the operator to verify that the cassette player is setup for writing (as above, plus REC button depressed). When the cassette is ready, the operator may press any keyboard key (except BREAK) to initiate tape writing. Note that there is no

way for the computer to verify that the REC button (or even the PLAY button) is depressed, so it is possible for the file not to be written, with no immediate indication of this fact.

There is a potential problem with the cassette in that when the cassette is OPENed for writing, the motor keeps running until the first record (128 data bytes) is written. If 128 data bytes are written or the cassette is CLOSEd within about 30 seconds of the OPEN, and no other serial bus I/O is performed, then there is no problem. However, if those conditions are not met, some noise will be written to the tape prior to the first record and an error will occur when that tape file is read later. If lengthy delays are anticipated between the time the cassette file is OPENed and the time that the first cassette record (128 data bytes) is written, then a dummy record should be written as part of the file; typically 128 bytes of some innocuous data would be written, such as all zeroes, all $FFs or all blanks ($20).

The system will sometimes emit whistling noises after cassette I/O has occurred. The sound can be eliminated by storing $03 to SKCTL [D20F], thus bring POKEY out of the two-tone (FSK) mode.

CLOSE

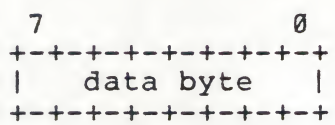
The CLOSE of a tape read stops the cassette motor.

The CLOSE of a tape write does the following:

Writes any remaining user data in the buffer to tape.
Writes an End-of-file record.
Stops the cassette motor.

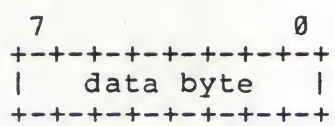
GET CHARACTERS and GET RECORD

The handler returns data in the following format:



PUT CHARACTERS and PUT RECORD

The handler accepts data in the following format:



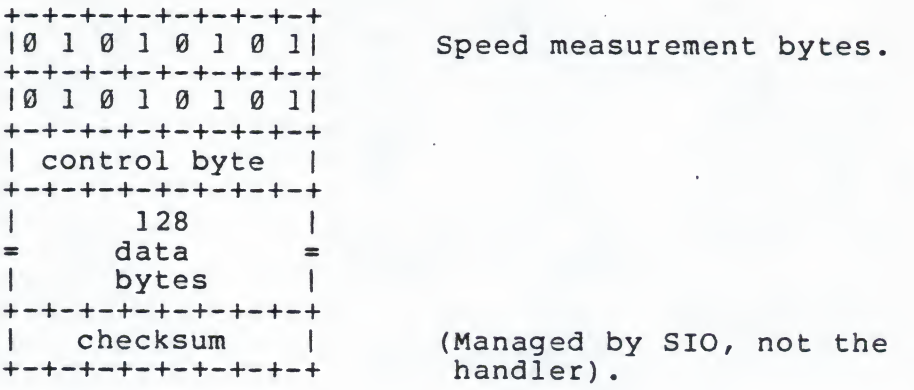
The handler attaches no significance to the data bytes written, a value of $9B (EOL) causes no special action.

GET STATUS

The handler does no more than set the status to $01.

Theory of operation.

The cassette handler writes and reads all data in fixed length records of the format shown below:



The control byte contains one of three values:

$FC indicates the record is a full data record (128 bytes).

$FA indicates the record is a partially full data record; fewer than 128 bytes were supplied by the user. This case may occur only in the record prior to the End-of-file. The number of user supplied data bytes in the record is contained in the byte prior to the checksum.

$FE indicates the record is an End-of file record; the data portion is all zeroes for an End-of-file record.

The checksum is generated and checked by the SIO routine and is part of the tape record, but is not contained in the handler's record buffer CASBUF [03FD].

The processing of the speed measurement bytes during cassette reading is discussed in section 4.5 D1-D7.

File structure

The Cassette handler writes a file to the cassette device with a file structure that is totally imposed by the handler (soft format). A file consists of the following three elements:

A 20 second leader of mark tone.
Any number of data record frames.
End-of file frame.

The cassette frames referred to above are formatted as shown below:

```
frame = pre-record write tone (PRWT),
        + data record,
        + post-record gap (PRG)
```

The non-data portions of a frame have characteristics which are dependent upon the write OPEN mode, i.e. continuous or start/stop.

Stop/start PRWT = 3 seconds of mark tone.
Continuous PRWT = .25 seconds of mark tone.

Stop/start PRG = up to 1 second of unknown tones.
Continuous PRG = from Ø to n seconds of unkonwn tones.

The inter-record gap (IRG) between any two records will thus consist of the PRG of the first record followed by the PRWT of the second record.

5.3.5 Printer handler (P:)

The Printer device is a write only device with a handler that supports the following CIO functions:

OPEN
CLOSE
PUT CHARACTERS
PUT RECORD
GET STATUS

The Printer handler may produce the following error statuses:

$8A-90 -- SIO error set (see Appendix C).

The Printer handler is one of the resident handlers, and therefore has a set of device vectors starting at location E430, as described further in section 5.4.1.

CIO function descriptions

The device specific characteristics of the standard CIO functions (described earlier in section 5.2.3) are detailed below:

OPEN

The device name is 'P', and the handler ignores any device number and filename specification, if included.

CLOSE

The handler writes any data remaining in its buffer to the printer device, with trailing blanks to fill out the line.

PUT CHARACTERS and PUT RECORD

The handler accepts print data in the following format:

```
 7             0
+-+-+-+-+-+-+-+-+
|    ATASCII    |
+-+-+-+-+-+-+-+-+
```

The only ATASCII control code of any significance to the handler is the EOL character. The printer device ignores bit-7 of every data byte and prints a sub-set of the remaining 128 codes, see Appendix G for the printer character set.

The handler supports the following print option:

```
 7             0
+-+-+-+-+-+-+-+-+
|  print mode   |
+-+-+-+-+-+-+-+-+
```

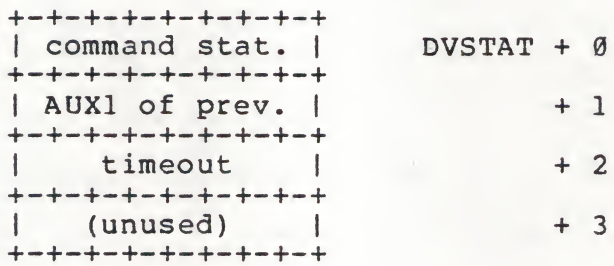
AUX2

Where: $4E ('N') selects normal printing (40 chars per line).
$53 ('S') selects sideways printing (29 chars per line).
$57 ('W') selects wide printing (not supported by

printer device.).
Any other value (including 00) is treated as a normal (N) print select, without producing an error status.

GET STATUS

The handler obtains a four byte status from the printer controller and puts it in system location DVSTAT [02EA]. The format of the status bytes is shown below:



The command status contains the following status bits:

Bit-0 indicates an invalid command frame was received.
Bit-1 indicates an invalid data frame was received.
Bit-7 indicates an intelligent controller (normally = 0).

The next byte contains the AUX1 value from the previous operation.

The timeout byte contains a controller provided maximum timeout value (in seconds).

Theory of operation.

The Atari 820 printer is a line at a time printer, rather than a character at a time printer, so the user data must be buffered by the handler and sent to the device in records corresponding to one print line (40 characters for normal, 29 characters for sideways).

The printer device does not attach any significance to the EOL character, so the handler does the appropriate blank fill whenever it sees an EOL.

5.3.6 Disk File Manager (D:)

At the time of this writing, there are four unique File Management Subsystems either in existence or under development. Version IA is the original version. Version IB is a slightly modified version of IA and is the one described in this document. Most of this discussion applies as well to Version II, which handles a double density disk (720 256-byte sectors) in addition to the single density disk (720 128-byte sectors). Version III has all new file/directory/map structures and possibly changes to the user interface as well.

The File Management Subsystem (FMS) includes a disk bootable (RAM resident) Disk File Manager which maintains a collection of named files on diskettes. Up to 4 disks (D1: through D4:) may be accessed, and up to 64 files per disk may be accessed; the system disks supplied by Atari allow a single disk drive (D1) and up to 3 OPEN files, but these numbers may be altered by the user as described later in this section. The Disk File Manager supports the following CIO functions:

```
OPEN FILE
OPEN DIRECTORY
CLOSE
GET CHARACTERS
GET RECORD
PUT CHARACTERS
PUT RECORD
GET STATUS

NOTE
POINT
LOCK
UNLOCK
DELETE
RENAME
FORMAT
```

The Disk File Manager may produce the following error statuses:

```
$03 -- Last data from file (EOF on next read).
$88 -- End-of-file.
$8A-90 -- SIO error set (see Appendix C).
$A0 -- Drive number specification error.
$A1 -- No sector buffer available (too many open files).
$A2 -- Disk full.
$A3 -- Fatal I/O error in directory or bitmap.
$A4 -- Internal file # mismatch (structural problem).
$A5 -- File name specification error.
$A6 -- Point information in error.
$A7 -- File locked to this operation.
$A8 -- Special command invalid.
$A9 -- Directory full (64 files).
$AA -- File not found.
$AB -- Point invalid (file not OPENed for update).
```

CIO function descriptions

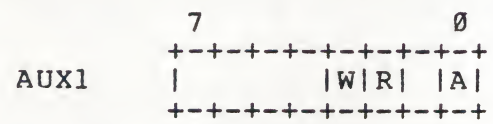
The device specific characteristics of the standard CIO functions (described earlier in section 5.2.3) are detailed

below:

OPEN FILE

The device name is 'D' and up to 4 disk drives may be accessed (D1 through D4); the disk filename may be from 1 to 12 characters in length.

The OPEN FILE command supports the following options:



Where: W & R are the direction bits.
WR = 00 is invalid
01 indicates OPEN for read only.
10 indicates OPEN for write only.
11 indicates OPEN for read/write (update).

A = 1 indicates appended output when W = 1.

The various valid AUX1 options are now explained.

OPEN input (AUX1 = $04)

The indicated file is OPENed for input. Any wild card characters are used to search for the first match. If the file is not found, an error status is returned, and no file will be OPENed.

OPEN output (AUX1 = $08)

The indicated file is OPENed for output starting with the first byte of the file, if the file is not locked. Any wild card characters are used to search for the first match. If the file already exists, the existing file will be DELETED before OPENing the named file as a new file. If the file does not already exist, it will be created.

A file OPENed for output will not appear in the directory until it has been CLOSEd. If an output file is not properly CLOSEd, some or all of the sectors that were acquired for it may be lost until the disk is reformatted.

OPEN append (AUX1 = $09)

The indicated file is OPENed for output starting with the byte after the last byte of the existing file (which must already exist), if the file is not locked. Any wild card characters are used to search for the first match.

If a file OPENed for append is not properly CLOSEd, the appended data will be lost, the existing file will remain unmodified and some or all of the sectors that were acquired for the appended portion may be lost until the disk is reformatted.

OPEN update (AUX1 = $0C)

The indicated file (which must already exist) will be *OPENed for* update provided it is not locked. Any wild card characters are used to search for the first match.

The GET, PUT, NOTE and POINT operations are all valid, and may be intermixed as desired.

If a file OPENed for update is not properly CLOSEd, a sector's worth of information may be lost to the file. A file OPENed for update may not be extended.

Device/filename specification

The handler expects to find a device/filename specification of the following form:

```
D[<number>]:<filename><EOL>
```

where:

```
<number> ::= [1|2|3|4]
<filename> ::= [<primary>][.[<extension>]]
```

<primary> ::= an upper case alpha character followed by 0 to 7 alphanumeric characters. If the primary name is less than 8 characters, it will be padded with blanks; if it is greater than 8 characters, the extra characters will be ignored.

<extension> ::= Zero to 3 alphanumeric characters. If the extension name is missing or less than 3 characters, it will be padded with blanks; if it is greater than 3 characters, the extra characters will be ignored.

The following are all valid device/filenames for the disk:

```
D1:GAME.SRC
D:MANUAL6
D:.WHY
D3:FILE.
D4:BRIDGE.002
```

Filename wildcarding

The filename specification may be further generalized to include the use of the "wildcard" characters '*' and '?'. These wildcard characters allow portions of the primary and/or extension to be abbreviated as follows:

The '?' character in the specification allows any file name character at that position to produce a "match". For example, WH? will match files named WHO, WHY, WH4, etc., but not a file named WHAT.

The '*' character causes the remainder of the primary or extension field in which it is used to be effectively padded with '?' characters. For example, WH* will match WHO, WHEN, WHATEVER, etc.

Some valid uses of wildcard specifications are shown below:

*.SRC	Files having an extension of SRC.
BASIC.*	Files named BASIC with any extension.
.	All files.
H*.?	Files beginning with H and having a 0 or 1 character extension.

If wildcarding is used with an OPEN FILE command, the first file found (if any) that meets the specification will be the one (and only one) opened.

OPEN DIRECTORY

The OPEN DIRECTORY command allows the user to read directory information for the selected filename(s), using normal GET CHARACTERS or GET RECORD commands. The information read will be formatted as ATASCII records, suitable for printing, as shown below. Wildcarding may be used to obtain information for multiple files or the entire disk.

The OPEN DIRECTORY command uses the same CIO parameters as a standard OPEN FILE command:

COMMAND BYTE = $03

BUFFER ADDRESS = pointer to device/filename specification.

AUX1 = $06

After the directory is OPENed, a record will be returned to the caller for each file that matches the OPEN specification. The record, which contains only ATASCII characters, is formatted as shown below:

```
                        1
 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|s|b| primary name  | ext |b|count|e|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where: s = '*' or ' ', with '*' indicating file locked.
b = blank.
primary name = left justified name with blank fill.
ext = left justified extension with blank fill.
b = blank.
count = number of sectors comprising the file.
e = EOL ($9B).

After the last filename match record is returned, an additional record is returned, which indicates the number of unused sectors available on the disk. The format for this record is shown below:

```
                        1
 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|count|  F R E E   S E C T O R S|e|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where: count = the number of unused sectors on the disk.
e = EOL ($9B).

The EOF statuses ($03 and $88) are returned as per a normal data file when the last directory record is read.

The OPENing of another disk file while the directory read is OPEN will cause subsequent directory reads to malfunction, so care must be taken to avoid this situation.

CLOSE

On closing a file read, the handler releases all internal resources being used to support that file.

On closing a file write, the handler writes any residual data from its file buffer for that file to the disk, updates the directory and allocation map for the associated disk, and releases all internal resources being utilized to support that file.

GET CHARACTERS and GET RECORD

Characters are read from the disk and passed to CIO as a raw data stream; none of the ATASCII control characters have any special significance.

$03 status on last byte (record)
$88 after that.

PUT CHARACTERS and PUT RECORD

Characters are obtained from CIO and written to the disk as a raw data stream; none of the ATASCII control characters have any special significance.

GET STATUS

The indicated file is checked and one of the following status byte values is returned in ICSTA and register Y:

$01 -- File found & unlocked.
$A7 -- File locked.
$AA -- File not found.

Special CIO functions

The DFM supports a number of SPECIAL commands, which are device specific; these are explained in the paragraphs that follow.

NOTE (COMMAND BYTE = $25)

This command returns to the caller the exact disk location of the next byte to be read or written, in the variables shown below:

ICAX3 = l.s.b. of the disk sector number.
ICAX4 = m.s.b. of the disk sector number.
ICAX5 = relative sector displacement to byte (0-124).

POINT (COMMAND BYTE = $26)

This command allows the user to specify the exact disk location

of the next byte to be read or written. In order to use this commmand, the file must have been OPENed with the "update" option.

ICAX3 = l.s.b. of the disk sector number.
ICAX4 = m.s.b. of the disk sector number.
ICAX5 = relative sector displacement to byte (0-124).

LOCK

This command allows the user to prevent write access to any number of named files. Locked files may not be deleted, renamed nor opened for output unless they are first unlocked. Locking a file that is already locked is a valid operation. The handler expects a defice/filename specification; then all occurrences of the filename specified will be locked, using the wildcard rules.

The following IOCB paramters are setup by the user prior to calling CIO:

COMMAND BYTE = $23

BUFFER ADDRESS = pointer to device/filename specification.

After a LOCK operation, the following IOCB parameter will have been altered:

STATUS = result of LOCK operation; see Appendix B for a list of possible status codes.

UNLOCK

This command allows the user to remove the lock status of any number of named files. Unlocking a file that is not locked is a valid operation. The handler expects a device/filename specification; then all occurrences of the filename specified will be unlocked, using the wildcard rules.

The following IOCB paramters are setup by the user prior to calling CIO:

COMMAND BYTE = $24

BUFFER ADDRESS = pointer to device/filename specification.

After an UNLOCK operation, the following IOCB parameter will have been altered:

STATUS = result of UNLOCK operation; see Appendix B for a list of possible status codes.

DELETE

This command allows the user to delete any number of unlocked named files from the directory of the selected disk and to deallocate the disk space used by the files involved. The handler expects a device/filename specification; then all occurences of the filename specified will be deleted, using the wildcard rules.

The following IOCB paramters are setup by the user prior to calling CIO:

COMMAND BYTE = $21

BUFFER ADDRESS = pointer to device/filename specification.

After a DELETE operation, the following IOCB parameter will have been altered:

STATUS = result of DELETE operation; see Appendix B for a list of possible status codes.

RENAME

This command allows the user to change the filenames of any number of unlocked files on a single disk. The handler expects to find a device/filename specification as shown below:

<device spec>:<filename spec>,<filename spec><EOL>

All occurrences of the first filename will be replaced with the second filename, using the wildcard rules. No protection is provided against forming duplicate names, and once formed, duplicate names cannot be separately renamed or deleted; however, an OPEN FILE command will always select the first file found that matches the filename specification, so that file will always be accessible. The RENAME command does not alter the content of the files involved, merely the name in the directory.

Examples of some valid RENAME name specifications are shown below:

```
D1:*.SRC,*.TXT
D:TEMP,FDATA
D2:F*,F*.OLD
```

The following IOCB paramters are setup by the user prior to calling CIO:

COMMAND BYTE = $20

BUFFER ADDRESS = pointer to device/filename specification.

After a RENAME operation, the following IOCB parameter will have been altered:

STATUS = result of RENAME operation; see Appendix B for a list of possible status codes.

FORMAT

This command allows the user to physically format a diskette, which is required before the diskette can be used to store data; the physical formatting process writes a new copy of every sector on the "soft sectored" diskette, with the data portion of each sector containing all zeroes. When the physical formatting process is complete, the FMS creates an initial Volume Table of Contents (VTOC) and an initial File Directory; as part of this process the boot sector (#1) is permanently reserved. The

result of the FORMAT process will be the creation of an "empty" non-system disk.

The following IOCB paramters are setup by the user prior to calling CIO:

COMMAND BYTE = $FE

BUFFER ADDRESS = pointer to device specification.

After a FORMAT operation, the following IOCB parameter will have been altered:

STATUS = result of FORMAT operation; see Appendix B for a list of possible status codes.

To create a system disk, a copy of the boot file must next be written to sectors #1-n. This is accomplished by writing the file named 'DOS.SYS', which is a name that is recognized by the FMS even though it is not in the directory initially.

Theory of operation

The resident O.S. initiates the disk boot process, as described in section 10.2, by reading disk sector #1 to memory and then transferring control to the "boot continuation address" (boot address + 6). The boot continuation program contained in sector #1 then continues to load the remainder of the File Management Subsystem to memory using additional information contained in sector #1. The File Management Subsystem loaded will contain a Disk File Manager and, optionally, a Disk Utilites (DOS) package.

When the boot process is complete, the Disk File Manager will allocate additional RAM for the creation of sector buffers. Sector buffers are allocated based upon information in the boot record as shown below:

Byte 9 = maximum number of OPEN files; one buffer per (the maximum value is 8).

Byte 10 = drive select bits; one buffer per (1-4 only).

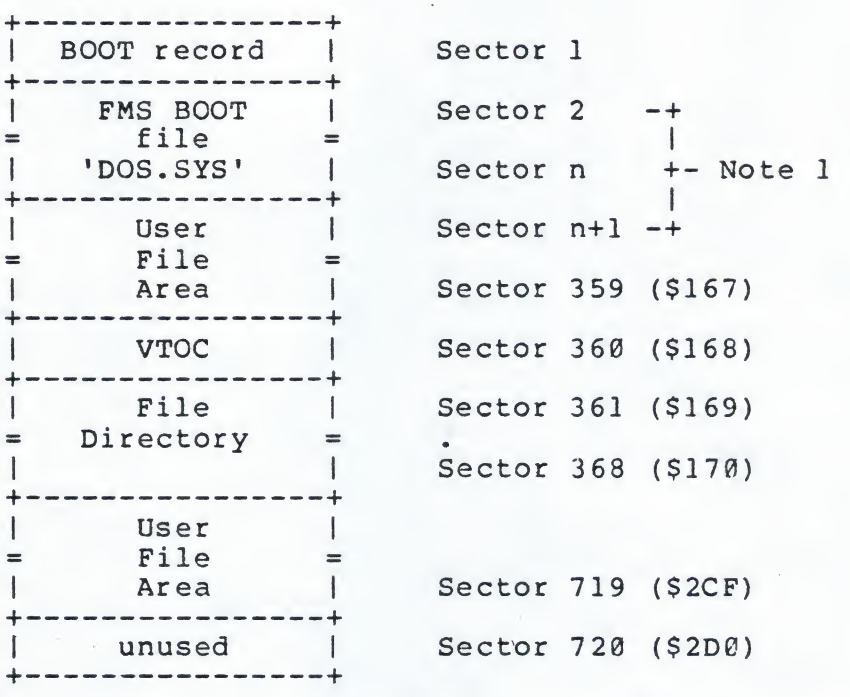
The Disk File Manager will then insert the name 'D' and the handler vector table address in the Device Table, as prescribed by section 9.1.

Note: there is a discrepancy between the Disk File Manager's numbering of disk sectors (0-719) and the disk controller's numbering of disk sectors (1-720); as a result, only sectors 1-719 are used by the Disk File Manager.

The Disk File Manager uses the Disk handler (as described in section 5.4.2) to perform all disk reads and writes; the DFM's function is to support and maintain the directory/file/bitmap structures as described in the following pages:

FMS DISK UTILIZATION

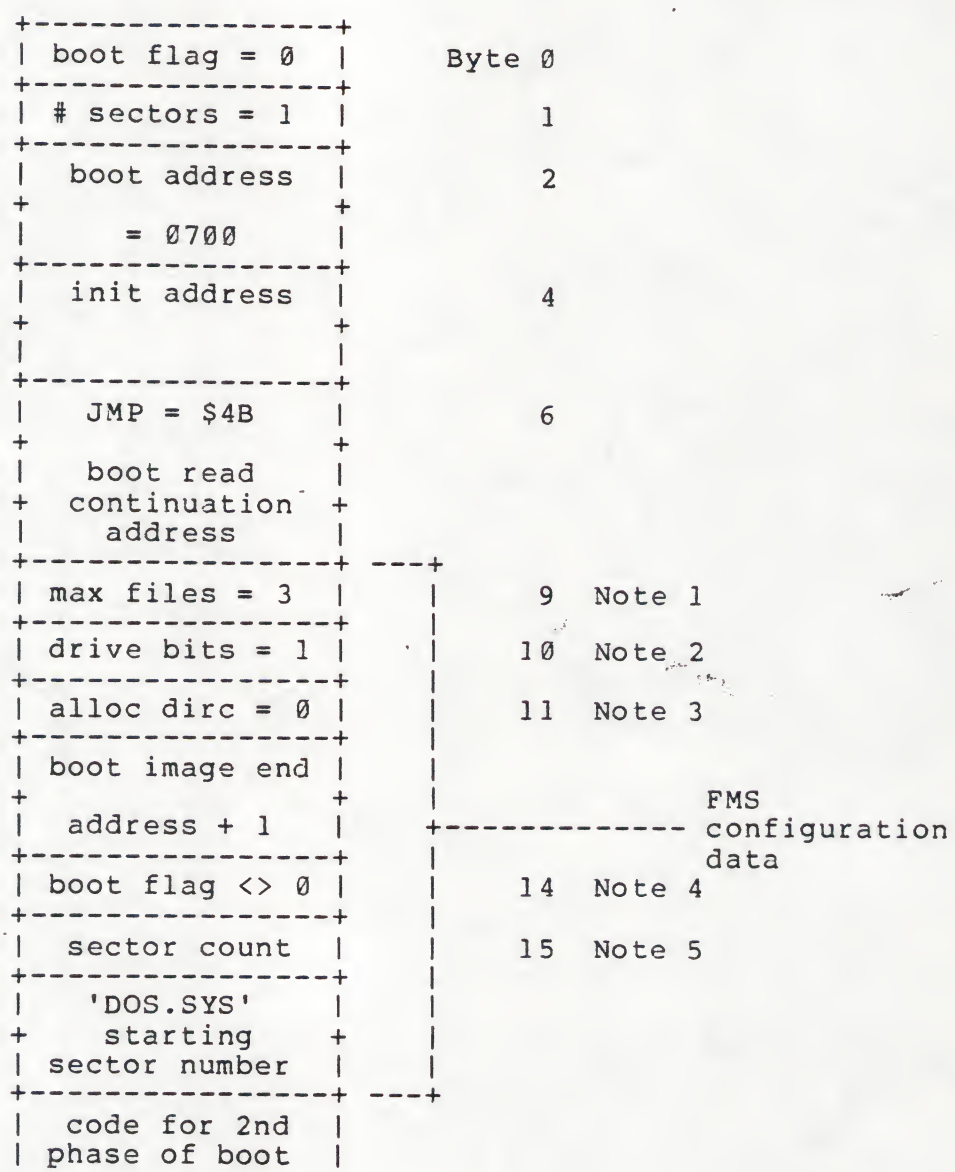
The map below shows the disk sector utilization for a standard 720 sector diskette.



Note 1 -- If the disk is not a system disk, then the User File Area starts at sector 2 and no space is reserved for the FMS BOOT file.

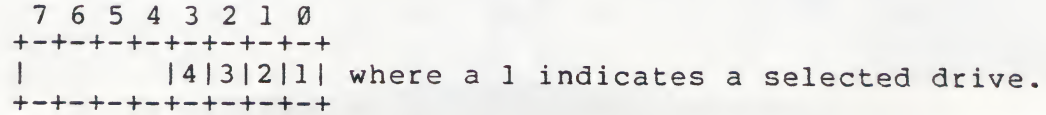
FMS BOOT RECORD FORMAT

The FMS BOOT record (sector #1) is a special case of disk booted software as described in section 10.2. The format for the FMS BOOT record is shown below:



Note 1 -- Byte 9 specifies the maximum number of concurrently OPEN files to be supported. This value may range from 1 to 8.

Note 2 -- Byte 10 specifies the specific disk drive numbers to be supported using a bit encoding scheme as shown below:



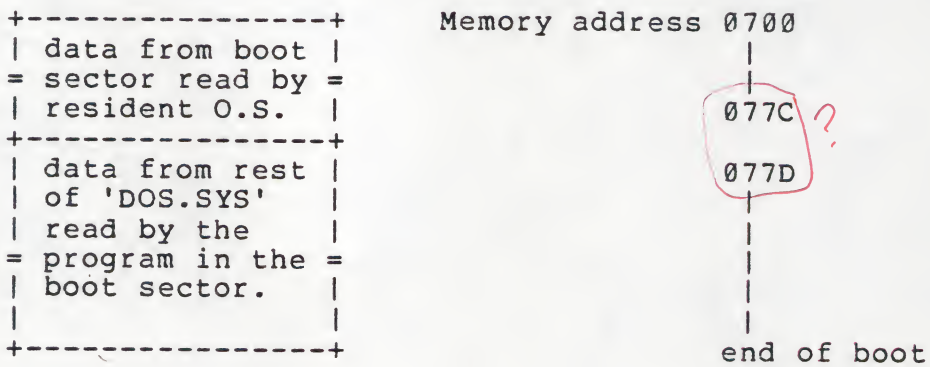
Note 3 -- Byte 11 specifies the buffer allocation direction, this byte should equal 0.

Note 4 -- Byte 14 must be non-zero for the second phase of the boot process to initiate; this flag indicates that the file 'DOS.SYS' has been written to the disk.

Note 5 -- This byte is assigned as being the sector count for the 'DOS.SYS' file, but is in actuality an unused byte.

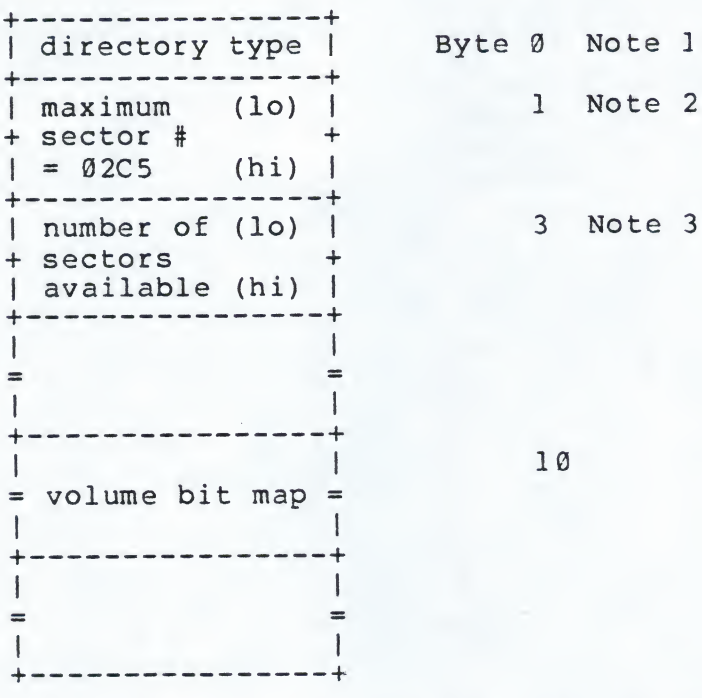
BOOT PROCESS MEMORY MAP

The diagram below shows how the boot sector (part of file DOS.SYS) and subsequent sectors are loaded to memory as part of the boot process.

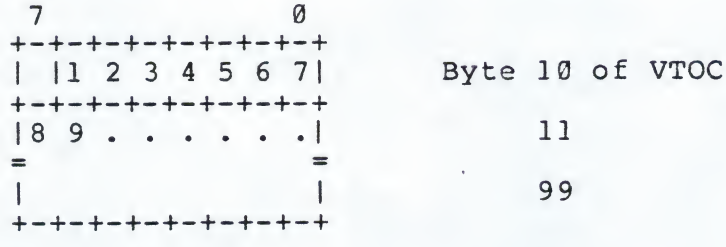


VOLUME TABLE OF CONTENTS (VTOC)

The format for the FMS volume table of contents (VTOC, sector 360) is shown in the diagram below:



Where the volume bit map is organized as shown below:



At each map bit position, a 0 indicates the corresponding sector is in use and a 1 indicates that the sector is available.

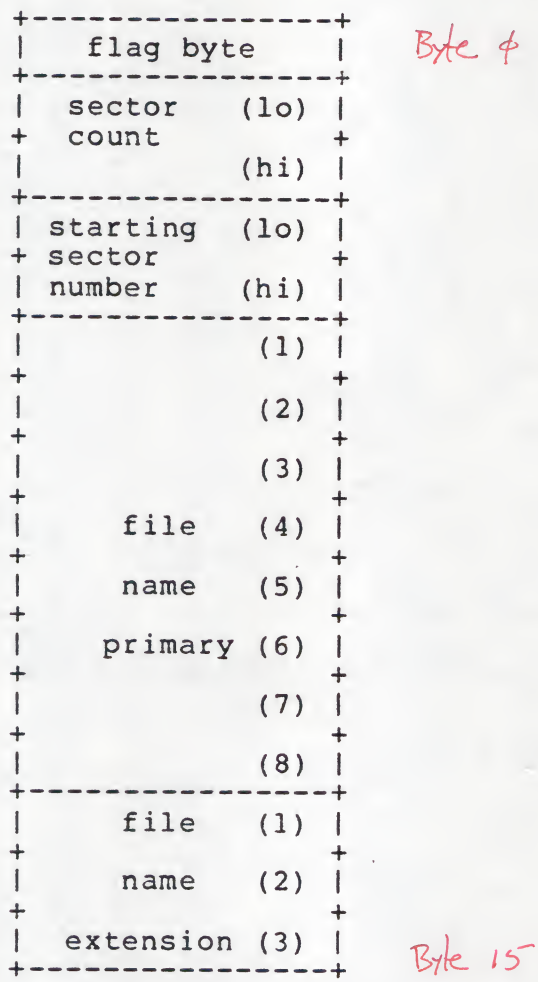
Note 1 -- The directory type byte must equal 0.

Note 2 -- The maximum sector number is apparently not used because it is incorrectly set to 709 decimal although the true maximum sector number is 719. for the FMS.

Note 3 -- The number of sectors available is initially set to 709 after a disk is freshly formatted; this number is adjusted as files are created and deleted to show the number of sectors available. The sectors which are initially reserved are 0-1 and 360-368.

FILE DIRECTORY FORMAT

There are eight sectors (361-368) reserved for a file directory, each sector containing directory information for up to eight files, thus providing for a maximum of 64 files for any volume. The format of a single file entry is shown below:



Where the flag byte has the following bits assigned:

Bit-7 = 1 if the file has been deleted.
Bit-6 = 1 if the file is in use.
Bit-5 = 1 if the file is locked.
Bit-0 = 1 if OPEN output.

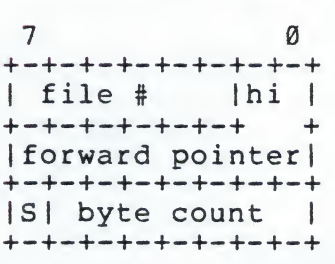
The flag byte may take on the following values:

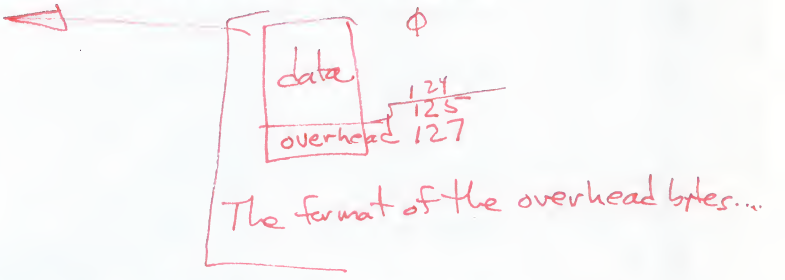
$00 = entry not yet used (no file).
$40 = entry in use (normal CLOSEd file).
$41 = entry in use (OPEN output file).
$60 = entry in use (locked file).
$80 = entry available (prior file deleted).

Sector count is the number of sectors comprising the file.

FMS FILE SECTOR FORMAT

The format of a sector in a user's data file is shown below:





The file # is a redundant piece of information which is used to verify file integrity; the file number field contains the value of the directory position of that file. If there is ever a mismatch between the file's position in the directory and the file number as contained in each sector, the Disk File Manager will generate the error $A4.

The forward pointer field contains the ten bit value of the disk sector number of the next sector of the file. The pointer will equal zero for the last sector of a file.

The S bit indicates whether or not the sector is a "short sector" (one containing fewer than 125 data bytes). S is equal to one when the sector is short.

The byte count field contains the number of data bytes in the sector.

5.4 Non-CIO I/O

Some portions of the I/O subsystem may or must be accessed independently of the Central I/O Utility (CIO); this section discusses those areas.

5.4.1 Resident device handler vectors

All of the O.S. ROM resident device handlers may be accessed via sets of vectors which are part of the O.S. ROM. The primary reason for using these vectors would be to increase the speed of I/O operations which utilize fixed device assignments, such as output to the Display handler. For each resident handler there is a set of vectors ordered as shown below:

```
+---------------+
+-    OPEN     -+      +0
+---------------+
+-   CLOSE     -+      +2
+---------------+
+-  GET BYTE   -+      +4
+---------------+
+-  PUT BYTE   -+      +6
+---------------+
+- GET STATUS  -+      +8
+---------------+
+-   SPECIAL   -+      +10
+---------------+
+-    JMP      -+      +12
+-    INIT     -+
+---------------+
```

See section 9.2 for a detailed description of the data interface for each of these handler entry points.

Each of the vectors contains the address (lo,hi) of the handler entry point minus one, so a technique similar to the one shown below is required to access the desired routines:

```
VTBASE=$E400                    ; BASE OF VECTOR TABLE.

      .
      LDX     #xx               ; OFFSET TO DESIRED ROUTINE.
      LDA     data
      JSR     GOVEC             ; SEND DATA TO ROUTINE.
      .
      LDX     #yy               ; OFFSET TO DIFFERENT ROUTINE.
      JSR     GOVEC             ; GET DATA FROM ROUTINE.
      STA     data
      .

GOVEC TAY                       ; SAVE REGISTER A.
      LDA     VTBASE+1,X        ; ADDRESS M.S.B. TO STACK.
      PHA
      LDA     VTBASE,X          ; ADDRESS L.S.B. TO STACK.
      PHA
      TYA                       ; RESTORE REGISTER A.
      RTS                       ; JUMP TO ROUTINE.
```

The JMP INIT slot in each set of vectors jumps to the handler

initialization entry (not minus one).

The base address of the vector set for each of the resident handlers is shown below:

Screen Editor (E:)	E400.
Display handler (S:)	E410.
Keyboard handler (K:)	E420.
Printer handler (P:)	E430.
Cassette handler (C:)	E440.

The resident disk handler is not CIO compatible, so its interface does not use a vector set; the disk handler interface is discussed in section 5.4.2.

5.4.2 Resident Disk handler

The resident Disk handler (not to be confused with the Disk File Manager discussed in section 5.3.6) is responsible for all physical accesses to the disk. The unit of data transfer for this handler is a single disk sector containing 128 data bytes.

Communication between the user and the Disk handler is effected using the system's Device Control Block (DCB), which is also used for handler/SIO communication as described in section 9.3. The DCB is twelve bytes long, in which some bytes are user alterable and some are for use by the Disk handler and/or the Serial I/O Utility (SIO). The user supplies the required DCB parameters and then does a JSR DSKINV [E453].

Each of the DCB bytes will now be described, and the system equate file name for each will be given.

SERIAL BUS I.D. -- DDEVIC [0300]

This byte is setup by the Disk handler to contain the Serial Bus I.D. for the drive to be accessed, and is not user alterable.

DEVICE NUMBER -- DUNIT [0301]

This byte is setup by the user and contains the disk drive number to be accessed (1 - 4).

COMMAND BYTE -- DCOMND [0302]

This byte contains the disk device command to be performed and is setup by the user.

STATUS BYTE -- DSTATS [0303]

This byte contains the status of the command upon return to the caller. See Appendix xx for a list of the possible status codes.

BUFFER ADDRESS -- DBUFLO [0304] & DBUFHI [0305]

This two byte pointer contains the address of the source or destination of the disk sector data. For the disk status command, the user need not supply an address; the Disk handler will obtain the status and insert the address of the status buffer in this field.

DISK TIMEOUT VALUE -- DTIMLO [0306]

This timeout value (in whole seconds) is supplied by the handler for use by SIO.

BYTE COUNT -- DBYTLO [0308] & DBYTHI [0309]

This two byte counter indicates the number of bytes transferred to or from the disk as a result of the most recent command, and is setup by the handler.

SECTOR NUMBER -- DAUX1 [030A] & DAUX2 [030B]

This two byte number specifies the disk sector number (0 - 719) to read or write. DAUX1 contains the least significant byte, and DAUX2 contains the most significant byte.

Disk handler commands

There are five commands supported by the Disk handler:

```
GET SECTOR
(PUT SECTOR --*** not supported by handler ***)
PUT SECTOR WITH VERIFY
STATUS REQUEST
FORMAT DISK
```

GET SECTOR (Command byte = $52)

The handler reads the specified sector to the user's buffer and returns the operation status. The following DCB parameters are set by the user prior to calling the Disk handler:

COMMAND BYTE = $52.

DEVICE NUMBER = disk drive number (1-4).

BUFFER ADDRESS = pointer to user's 128 byte buffer.

SECTOR NUMBER = sector number to read.

Upon return, several of the other DCB parameters will have been altered, however, the STATUS BYTE will be the only one of interest to the user.

PUT SECTOR (Command byte = $50)

*** Not supported by current handler ***

The handler writes the specified sector from the user's buffer and returns the operation status. The following DCB parameters are set by the user prior to calling the Disk handler:

COMMAND BYTE = $50.

DEVICE NUMBER = disk drive number (1-4).

BUFFER ADDRESS = pointer to user's 128 byte buffer.

SECTOR NUMBER = sector number to write.

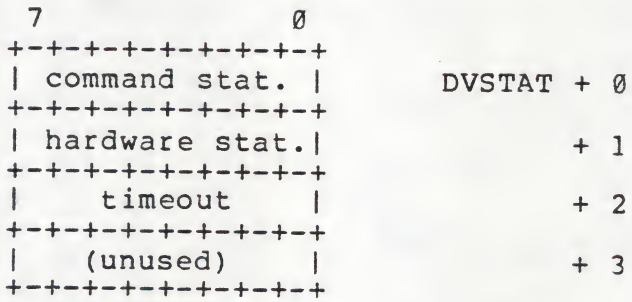
Upon return, several of the other DCB parameters will have been altered, however, the STATUS BYTE will be the only one of interest to the user.

PUT SECTOR WITH VERIFY (Command byte = $57)

The handler writes the specified sector from the user's buffer and returns the operation status. This command differs from PUT SECTOR in that the disk controller reads the sector data after writing to verify the write operation. (byte by byte compare???) Aside from the COMMAND BYTE value, the calling sequence is identical to PUT SECTOR.

STATUS REQUEST (Command byte = $53)

The handler obtains a four byte status from the disk controller and puts it in system location DVSTAT [02EA]. The operation status format is shown below:



The command status contains the following status bits:

Bit-0 = 1 indicates an invalid command frame was received.
Bit-1 = 1 indicates an invalid data frame was received.
Bit-2 = 1 indicates that a PUT operation was unsuccessful.
Bit-3 = 1 indicates that the disk is write protected.
Bit-4 = 1 indicates active/standby.

The hardware status byte contains the status register of the INS1771-1 Floppy Disk Controller chip used in the disk controller. See the documentation for that chip for information relating to the meaning of each bit in the byte.

The timeout byte contains a controller provided maximum timeout value (in seconds) to be used by the handler.

The following DCB parameters are set by the user prior to calling the Disk handler:

COMMAND BYTE = $53.

DEVICE NUMBER = disk drive number (1-4).

Upon return, several of the other DCB parameters will have been altered, however, the STATUS BYTE will be the only one of interest to the user.

FORMAT DISK (Command byte = $21)

The handler commands the disk controller to format the entire disk and then to verify it. All bad sector numbers, up to a maximum of 63, are returned and put in the supplied buffer, followed by two bytes of all ones ($FFFF). The following DCB parameters are set by the user prior to calling the Disk handler:

COMMAND BYTE = $21.

DEVICE NUMBER = disk drive number (1-4).

BUFFER ADDRESS = pointer to user's 128 byte buffer.

Upon return, the following DCB parameters will be of interest to

the user:

STATUS BYTE = status of operation.

BYTE COUNT = number of bytes of bad sector information in user's buffer, not including the $FFFF terminator. If there are no bad sectors, the count will equal zero.

5.4.3 Dorsett format cassettes

Dorsett, or Educational System, format cassette tapes are recorded in 1/4 track stereo format at 1 7/8 inches per second. The tape can be recorded in both directions, where tracks 1 and 2 are side A left and right; and trcks 3 and 4 are side B right and left (industry standard). On each side, the left channel (1 or 4) is used for audio and the right channel (2 or 3) is used for digital information.

The audio channel is recorded in the normal manner. The digital channel is recorded using unknown techniques and it is not known if the recording is continuous, asynchronous byte, asynchronous record or some other format. *

The character set is thought to be similar to ASCII. *

All data on the tape is stored in bit inverted form; that is, all zero bits are stored as one bits and vice versa.

* Obviously this is information is known, just not by the author of this document. This situation will be corrected soon.

5.4.4 Serial bus I/O (SIO)

Input/Output to devices other than the keyboard, the screen and the Atari controller port devices must utilize the Serial I/O bus. This bus contains data, control and clock lines to be used to allow the computer to communicate with external devices on this "daisy chained" bus. Every device on the bus has a unique identifier and will respond only when directly addressed.

The resident system provides a Serial I/O Utility (SIO), which provides a standardized high-level program interface to the bus. SIO is utilized by the resident Disk, Printer and Cassette handlers and is intended to be used by non-resident handlers (as described in section 9.3) or by applications, as well. For a detailed description of the program/SIO interface refer to section 9.3 and for a detailed bus specification refer to section 9.4.

5.5 Device characteristics

This section describes the physical characteristics of the devices that interface to the Atari 400/800. Where applicable, data capacity, data transfer rate, storage format, SIO interface and cabling will be detailed.

5.5.1 Keyboard

The keyboard input rate is limited by the O.S. keyboard reading procedure to be 60 characters per second. The code for each key is shown as a table in section 5.3.1. A picture of the Atari 400 keyboard is shown on the following page. The keyboard hardware has no buffering.

5.5.2 Display

The TV display generator has many capabilities that are not used by the Display handler (as described in section 5.3.2 and shown in Appendix H); there are additional display modes, object generators, hardware display scrolling and many other features which are described in the CANDY/COLLEEN HARDWARE MANUAL.

Since all display data is stored in RAM, the display data update rate is limited primarily by the software routines that generate and format the data and access the RAM. The generation of the display from the RAM is accomplished by the ANTIC and CTIA chips using Direct Memory Access (DMA) to access the RAM data.

The internal storage formats for display data for the various modes are detailed in the CANDY/COLLEEN HARDWARE MANUAL.

5.5.3 Cassette (410)

The Atari 410 cassette has the following characteristics:

DATA CAPACITY:

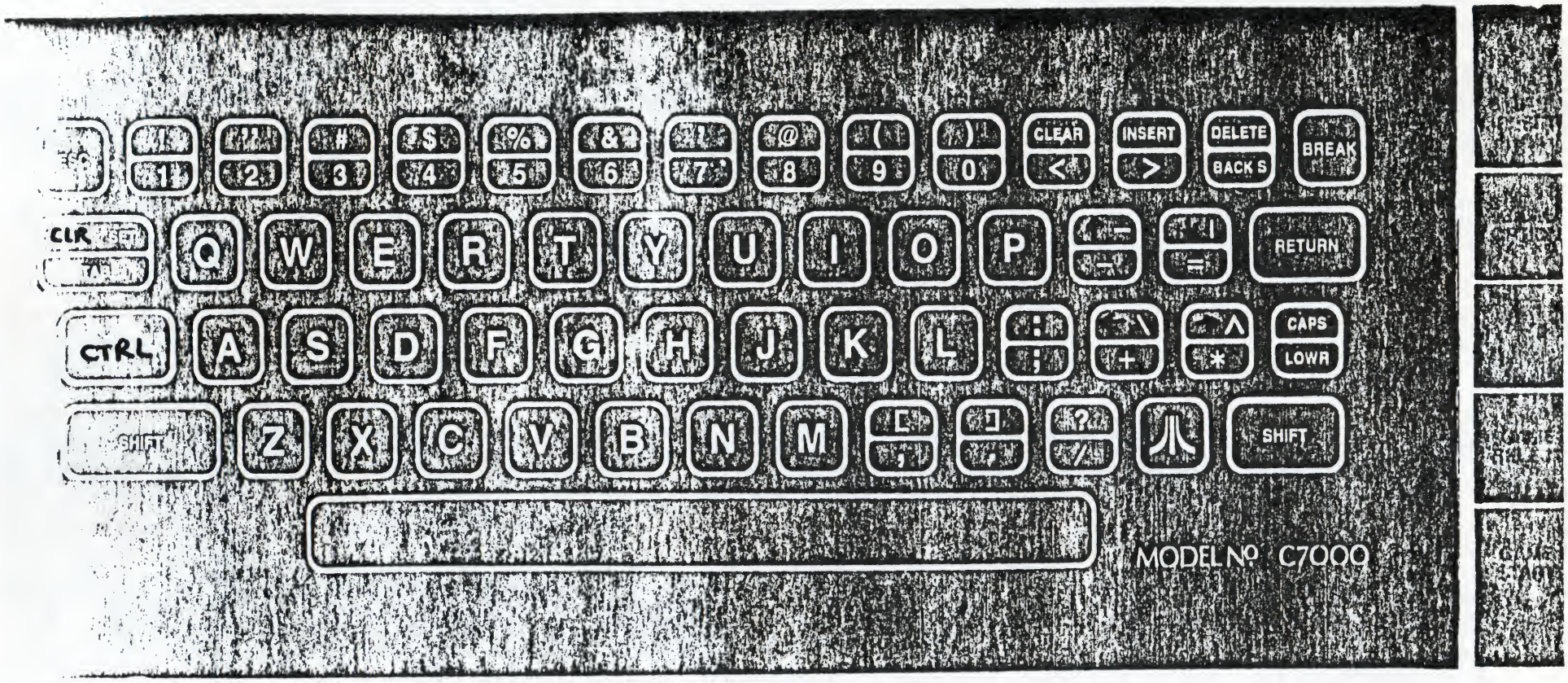
xx characters per C-60 tape (unformatted).
xx characters per C-60 tape (formatted, continuous).
xx characters per C-60 tape (formatted, stop/start).

DATA TRANSFER RATES:

xx characters per second (unformatted).
xx characters per second, average (formatted, stop/start).

STORAGE FORMAT:

Tapes are recorded in 1/4 track stereo format at 1 7/8 inches per second. The tape can be recorded in both directions, where tracks 1 and 2 are side A left and right; and tracks 3 and 4 are side B right and left (industry standard). On each side, the left channel (1 or 4) is used for audio and the right channel


CLEAR
INSERT
DELETE
BACK S
BREAK
CLR
RETURN
CTRL
CAPS
LOWR
SHIFT
SHIFT
MODEL Nº C7000

(2 and 3) is used for digital information.

The audio channel is recorded the normal way. The digital channel is recorded using the POKEY two-tone mode producing FSK data at up to 600 baud. The MARK frequency is 5327 Hz and the SPACE frequency is 3995 Hz. The transmission of data is asynchronous byte serial as seen from the computer; POKEY reads or writes a bit serial FSK sequence for each byte, in the following order:

```
1 start bit (SPACE)
data bit-0 -+
data bit-1  |
.           +-  0 = SPACE, 1 = MARK.
data bit-6  |
data bit-7 -+
1 stop bit (MARK)
```

The only control the computer has over tape motion is motor start/stop; and this only if the PLAY button is pressed by the user. In order for recording to take place, the user must press both the REC and PLAY buttons on the cassette. The computer has no way to sense the position of these buttons, nor even if a 410 is cabled to the computer, so the user must be careful when using this device.

SIO INTERFACE

The cassette device utilizes portions of the serial bus hardware, but does not follow any of the protocol as defined in section 9.4.

5.5.4 Printer (820)

The Atari 820 printer has the following characteristics:

DATA CAPACITY:

40 characters per line (normal printing)
29 characters per line (sideways printing)

DATA TRANSFER RATES:

Bus rate: xx characters per second.
Print time (burst): xx characters per second.
Print time (average): xx characters per second.

STORAGE FORMAT:

3 7/8 inch wide paper.
5X7 dot matrix, impact printing.

Normal format --
40 characters per line.
6 lines per inch (vertical).
12 characters per inch (horizontal).

Sideways format --

29 characters per line.
6 lines per inch (vertical).
9 characters per inch (horizontal).

SIO INTERFACE

The controller serial bus I.D. is $40.

The controller supports the following SIO commands (see section 5.3.3 for more information regarding the handler and section 9.4.2 for a general discussion of bus commands):

GET STATUS

The computer sends a command frame of the format shown below:

```
Device I.D.  = $40.
Command byte = $53.
Auxilliary 1 = doesn't matter.
Auxilliary 2 = doesn't matter.
Checksum     = checksum of bytes above.
```

The printer controller responds with a data frame of the format shown in section 5.3.5 as part of the GET STATUS discussion.

PRINT LINE

The computer sends a command frame of the format shown below:

```
Device I.D.  = $40.
Command byte = $57.
Auxilliary 1 = doesn't matter.
Auxilliary 2 = $4E for normal print or $53 for sideways.
Checksum     = checksum of bytes above.
```

The computer sends a data frame of the format shown below:

```
Leftmost character of line (column 1).
Next character of line (column 2).
.
.
Rightmost character of line (column 40 or 29).
Checksum byte.
```

Note that the data frame size is variable, either 41 or 30 bytes in length, depending upon the print mode specified in the command frame.

5.5.5 Disk (810)

The Atari 810 disk has the following characteristics:

DATA CAPACITY:

720 sectors of 128 bytes each (Disk handler format).
709 sectors of 125 data bytes each (Disk File Manager format).

DATA TRANSFER RATES:

Bus rate: xx characters per second.
Seek time: xx msec. per track + xx msec.
Rotational latency: xx msec maximum (xx rpm).

STORAGE FORMAT:

5 1/4 inch diskette, soft sectored by the controller.
40 tracks per diskette.
18 sectors per track.
128 bytes per sector.
Controlled by National INS1771-1 formatter/controller chip.

SIO INTERFACE

The controller serial bus I.D.s range from $31 (for 'D1') to $34 (for 'D4').

The controller supports the following SIO commands (see section 5.4.2 for information about the disk handler and section 9.4.2 for a general discussion of bus commands):

GET STATUS

The computer sends a command frame of the format shown below:

Device I.D. = $31-34.
Command byte = $53.
Auxilliary 1 = doesn't matter.
Auxilliary 2 = doesn't matter.
Checksum = checksum of bytes above.

The disk controller responds with a data frame of the format shown in section 5.4.2 as part of the STATUS REQUEST discussion.

PUT SECTOR (WITH VERIFY)

The computer sends a command frame of the format shown below:

Device I.D. = $31-34
Command byte = $57.
Auxilliary 1 = low byte of sector number.
Auxilliary 2 = high byte of sector number (1-720).
Checksum = checksum of bytes above.

The computer sends a data frame of the format shown below:

128 data bytes.
Checksum byte.

The disk controller writes the frame data to the specified sector, then reads the sector and compares the content with the frame data. The COMPLETE byte value indicates the status of the operation.

PUT SECTOR (NO VERIFY)

The computer sends a command frame of the format shown below:

Device I.D. = $31-34
Command byte = $50.

```
Auxilliary 1 = low byte of sector number.
Auxilliary 2 = high byte of sector number (1-720).
Checksum     = checksum of bytes above.
```

The computer sends a data frame of the format shown below:

```
128 data bytes.
Checksum byte.
```

The disk controller writes the frame data to the specified sector, then sends a COMPLETE byte value which indicates the status of the operation.

GET SECTOR

The computer sends a command frame of the format shown below:

```
Device I.D.  = $31-34
Command byte = $52.
Auxilliary 1 = low byte of sector number.
Auxilliary 2 = high byte of sector number (1-720).
Checksum     = checksum of bytes above.
```

The disk controller sends a data frame of the format shown below:

```
128 data bytes.
Checksum byte.
```

FORMAT DISK

The computer sends a command frame of the format shown below:

```
Device I.D.  = $31-34
Command byte = $21.
Auxilliary 1 = doesn't matter.
Auxilliary 2 = doesn't matter.
Checksum     = checksum of bytes above.
```

The disk controller completely formats the disk (generates 40 tracks of 18 soft sectors per track with the data portion of each sector equal to all zeroes) and then reads each sector to verify its integrity. A data frame of 128 bytes plus checksum is returned in which the sector numbers of all bad sectors (up to a maximum of 63 sectors) are contained, followed by two consecutive bytes of $FF. If there are no bad sectors on the disk the first two bytes of the data frame will contain $FF.

5.5.6 RS-232 (xxx)

No information at the time of this writing.

DATA CAPACITY:

DATA TRANSFER RATES:

STORAGE FORMAT:

.

SIO INTERFACE:

6. Interrupt processing.

6.1 Overview

There are three general interrupt types processed by the 6502 microcomputer: chip reset, non-maskable interrupts (NMI) and maskable interrupts (IRQ). The IRQ type may be enabled and disabled using the 6502 CLI and SEI instructions, whereas the NMI type may not be disabled at the processor level; the NMI interrupts other than RESET key may be disabled at the ANTIC chip, however.

The system events that can cause interrupts are listed below:

Chip reset - Power-up

NMI - Display list interrupt (unused by O.S.)
Vertical blank (50/60 Hz)
RESET key

IRQ - Serial bus output ready
Serial bus output complete
Serial bus input ready
Serial bus proceed line (unused by system)
Serial bus interrupt line (unused by system)
POKEY timers 1, 2 & 4
Keyboard key
BREAK key
6502 BRK instruction (unused by O.S.)

The chip reset interrupt is vectored via location FFFC to E477 where a JMP vector to the power-up routine is located. All NMI interrupts are vectored via location FFFA to the NMI interrupt service routine at E7B4 and all IRQ interrupts are vectored via location FFFE to the IRQ interrupt service routine at E6F3, at which point the cause of the interrupt must be determined by a series of tests. For some of the events there are built in monitor actions and for other events the corresponding interrupts are disabled or ignored. The system provides RAM vectors so that the user may intercept interrupts when necessary.

The remainder of section 6 will describe system actions for the various interrupt causing events, define the many RAM vectors and provide recommended procedures for dealing with interrupts.

6.2 Chip reset

Chip reset is generated in response to a power-up condition. The system is completely initialized as described in section 7.

6.3 Non-maskable interrupts (NMI)

When an NMI interrupt occurs, control is transferred through the ROM vector directly to the system NMI interrupt service routine, where a cause for the interrupt is determined by examining hardware register NMIST [D40F]. If a display list interrupt is pending, a jump is made through the global RAM vector VDSLST [0200]; the O.S. does not use display list interrupts so VDSLST is initialized to point to an RTI instruction and must be

changed by the user before a display interrupt is allowed to be generated.

If the interrupt is not a display list interrupt, then a test is made to see if it is a RESET key interrupt; if so, then a jump is made to the RESET initialization routine (see section 7 for details of RESET initialization).

If the interrupt is neither a display list interrupt nor a RESET key interrupt then it is assumed to be a vertical blank (VBLANK) interrupt and the following actions occur:

Registers A,X & Y are pushed to the stack.

The interrupt request is cleared (NMIRES [D40F]).

A jump is made through the "immediate" vertical blank global RAM vector VVBLKI [0222] which normally points to the stage 1 VBLANK processor.

Assuming that VVBLKI has not been changed by the user, the following actions occur:

The stage 1 VBLANK processor is executed (see section 6.3.1).

Tests are made to see if a critical code section has been interrupted;if so, all registers are restored and an RTI instruction returns from the interrupt to the critical section. A critical section is determined by examining the CRITIC flag [0042] and the processor I bit; if either are set then the interrupted section is assumed to be critical.

If the interrupt was not from a critical section, then the stage 2 VBLANK processor is executed (see section 6.3.2).

A jump is then made through the "deferred" vertical blank global RAM vector VVBLKD [0224] which normally points to the VBLANK exit routine.

Assuming that VVBLKD has not been changed by the user, the following actions occur:

The 6502 A,X & Y registers are restored.

An RTI instruction is executed.

Note that there are ROM vectors to the stage 1 VBLANK processor and to the VBLANK exit routine available to the user who alters the deferred and immediate VBLANK RAM vectors but still wants to enable normal system processes as well or restore the original vectors without having to save them. The instruction at E45F is a JMP to the stage 1 VBLANK processor; the address at [E460,2] is the value normally found in VVBLKI. The instruction at E462 is a JMP to the VBLANK exit routine; the address at [E463,2] is the value normally found in VVBLKD.

Note also that a jump is made through vector VVBLKI on every VBLANK interrupt, but a jump is made through vector VVBLKD only on interrupts from non-critical code sections. Care to take a

guess about percentages?

6.3.1 Stage 1 VBLANK process

As part of the stage 1 VBLANK processing which will be performed at every VBLANK interrupt are the following:

The 3 byte frame counter RTCLOK [0012-0014] is incremented; RTCLOK+0 is the MSB and RTCLOK+2 is the LSB. This counter wraps to zero when it overflows (every 77 hours or so) and continues counting.

The Attract mode variables are processed as described in section 4.5 B10-12.

System timer 1 CDTMV1 [0218,2] is decremented if it is non-zero; if the timer goes from non-zero to zero then an indirect JSR is performed via CDTMA1 [0226,2].

6.3.2 Stage 2 VBLANK process

As part of the stage 2 VBLANK processing which will be performed at those VBLANK interrupts which do not interrupt critical sections are the following:

The 6502 processor I bit is cleared, thus enabling the IRQ interrupts.

Various hardware registers are updated with data from the O.S. database as shown below.

Database item	Hardware reg.	Reason for update
SDLSTH [0231]	DLISTH [D403]	Display list end.
SDLSTL [0230]	DLISTL [D402]	
SDMCTL [022F]	DMACTL [D400]	
CHBAS [02F4]	CHBASE [D409]	
CHACT [02F3]	CHACTL [D401]	
GPRIOR [026F]	PRIOR [D01B]	
COLOR0 [02C4]	COLPF0 [D016]	Attrace mode.
COLOR1 [02C5]	COLPF1 [D017]	
COLOR2 [02C6]	COLPF2 [D018]	
COLOR3 [02C7]	COLPF3 [D019]	
COLOR4 [02C8]	COLBK [D01A]	
PCOLR0 [02C0]	COLPM0 [D012]	
PCOLR1 [02C1]	COLPM1 [D013]	
PCOLR2 [02C2]	COLPM2 [D014]	
PCOLR3 [02C3]	COLPM3 [D015]	
Constant = 8	CONSOL [D01F]	Console speaker off.

System timer 2 CDTMV2 [021A,2] is decremented if it is non-zero; if the timer goes from non-zero to zero then an indirect JMS is performed through CDTMA2 [0228,2].

System timers 3, 4 & 5 are decremented if non-zero; the corresponding flags are set to zero for each timer that changes from non-zero to zero.

Timer	Timer value	Timer flag
3	CDTMV3 [021C,2]	CDTMF3 [022A,1]
4	CDTMV4 [021E,2]	CDTMF4 [022C,1]
5	CDTMV5 [0220,2]	CDTMF5 [022E,1]

A character is read from the POKEY keyboard register and stored in CH [02FC] if auto-repeat is active.

The keyboard debounce counter is decremented if not equal to zero and if no key is pressed.

Keyboard auto-repeat is processed as described in section 4.5 E8.

Game controller data is read from the hardware to the RAM database as shown below.

Hardware reg.		Database item		Function
PENV	[D40D]	LPENV	[0235]	Lightpen.
PENH	[D40C]	LPENH	[0234]	
PORTA	[D300]	STICK0	[0278]	Joysticks &
		STICK1	[0279]	
		PTRIGn		pot triggers.
PORTB	[D301]	STICK2	[027A]	
		STICK3	[027B]	
		PTRIGn		
POT0	[D200]	PADDL0	[0270]	Pot controllers.
.		.		
POT7	[D207]	PADDL7	[0277]	
TRIG0	[D001]	STRIG0	[0284]	Joystick triggers.
.		.		
TRIG3	[D004]	STRIG3	[0287]	

6.4 Maskable interrupts (IRQ)

When an IRQ interrupt occurs control is transferred through the immediate IRQ global RAM vector VIMIRQ [0216]; ordinarily this vector points to the system IRQ handler whose actions are described below.

A cause for the interrupt is found by examining the IRQST [D20E] register and the PIA status registers PACTL [D302] & PBCTL [D303]. For the interrupt found, the interrupt status bit is cleared. One interrupt event is cleared and processed for each interrupt service entry; if multiple IRQs are pending a separate interrupt will be generated for each until all are serviced.

The rest of this section describes how the system IRQ interrupt service routine deals with each of the possible IRQ causing events.

The 6502 A register is pushed to the stack.

If the interrupt is due to serial I/O bus output ready, then clear the interrupt and jump through global RAM vector VSEROR [020C].

If the interrupt is due to serial I/O bus input ready, then

clear the interrupt and jump through global RAM vector VSERIN [020A].

If the interrupt is due to serial I/O bus output complete, then clear the interrupt and jump through global RAM vector VSEROC [020E].

If the interrupt is due to POKEY timer #1, then clear the interrupt and jump through global RAM vector VTIMR1 [0210].

If the interrupt is due to POKEY timer #2, then clear the interrupt and jump through global RAM vector VTIMR2 [0212].

If the interrupt is due to POKEY timer #4, then clear the interrupt and fall into the following test due to a bug in the O.S. interrupt processor!

If the interrupt is due to a keyboard key being pressed (other than BREAK,START,OPTION,SELECT), then clear the interrupt and jump through global RAM vector VKEYBD [0208].

If the interrupt is due to the BREAK key being pressed, then clear the interrupt, set the BREAK flag BRKKEY [0011] to zero, and clear the following: start/stop flag SSFLAG [02FF], cursor inhibit flag CRSINH [02F0] and Attract mode flag ATRACT [004D]. Then return from the interrupt after restoring the 6502 A register from the stack.

If the interrupt is due to the serial I/O bus proceed line, then clear the interrupt and jump through global RAM vector VPRCED [0202].

If the interrupt is due to the serial I/O bus interrupt line, then clear the interrupt and jump through global RAM vector VINTER [0204].

If the interrupt is due to a 6502 BRK instruction, then jump through global RAM vector VBREAK [0206].

If none of the above, restore the 6502 A register and return from the interrupt (RTI).

6.5 Interrupt initialization

Whenever the system is powered up or the RESET key is pressed, the interrupt subsystem is completely re-initialized. The hardware registers are all cleared and the interrupt global RAM vectors are set to the following configurations:

Vector	Value	Type	Function
VDSLST [0200]	E7B3	NMI	RTI -- ignore interrupt.
VVBLKI [0222]	E7D1	"	System stage 1 VBLANK.
CDTMA1 [0226]	EBF0	"	SIO timeout timer.
CDTMA2 [0228]	0000	"	No system function.
VVBLKD [0224]	E93E	"	System return from int.
VIMIRQ [0216]	E6F6	IRQ	System IRQ processor.
VSEROR [020C]	EA90	"	SIO.
VSERIN [020A]	EB11	"	SIO.

```
VSEROC [020E]  EAD1      "      SIO.
VTIMR1 [0210]  E7B2      "      PLA,RTI -- ignore int.
VTIMR2 [0212]  E7B2      "      PLA,RTI -- ignore int.
VTIMR4 [0214]  E7B2      "      *** doesn't matter ***
VKEYBD [0208]  FFBE      "      System keyboard int. handler.
VPRCED [0202]  E7B2      "      PLA,RTI -- ignore int.
VINTER [0204]  E7B2      "      PLA,RTI -- ignore int.

VBREAK [0206]  E7B2    BRK      PLA,RTI -- ignore int.
```

After system initialization is complete, the interrupt enable situation is as follows:

NMI VBLANK enabled, Display list disabled.

IRQ BREAK key and data key interrupts enabled, all others disabled.

6.6 System timers

There are five general purpose software timers plus a frame counter supported by the O.S. The timers are two bytes in length (lo,hi) and the frame counter RTCLOK [0012] is three bytes in length (hi,mid,lo). The timers count downward from any non-zero value to zero and upon reaching zero then either clear an associated flag or JSR through a RAM vector. The frame counter counts upward, wrapping to zero when it overflows. The table below shows the timers and the frame counter characteristics:

	Timer name	Flag/vector	Use
*	CDTMV1 [0218]	CDTMA1 [0226]	2 byte vector -- SIO timeout.
	CDTMV2 [021A]	CDTMA2 [0228]	2 byte vector
	CDTMV3 [021C]	CDTMF3 [022A]	1 byte flag
	CDTMV4 [021E]	CDTMF4 [022C]	1 byte flag
	CDTMV5 [0220]	CDTMF5 [022E]	1 byte flag
*	RTCLOK [0012]		3 byte frame counter.

* These timers are maintained as part of every VBLANK interrupt (stage 1 process); the other timers are subject to the critical section test (stage 2 process) which may defer their updating to a later VBLANK interrupt.

6.7 Usage notes

This subsection describes the "tricks" that must be known in order for the user to utilize interrupts in conjunction with the operating system.

6.7.1 POKEY interrupt mask

ANTIC (display list & vertical blank) and PIA (interrupt & proceed lines) interrupts may be masked directly as described in the Candy/Colleen Hardware Manual. However, the POKEY interrupts (BREAK key, data key, serial input ready, serial output ready, serial output done and timers 1,2 & 4) are all masked by the eight bits of a single byte IRQEN [D20E] which happens to be a write-only register. Thus, in order to selectively update individual interrupt mask bits, while not

changing the other bits, we must maintain a current value of that register in RAM. The name of the variable used is POKMSK [0010] and it is used as shown in the examples below:

```
; EXAMPLE OF INTERRUPT ENABLE

        SEI             ; TO AVOID CONFLICT WITH IRQ ...
        LDA     POKMSK  ; ... PROCESSOR WHICH ALTERS VAR.
        ORA     #$xx    ; ENABLE BIT(S).
        STA     POKMSK
        STA     IRQEN   ; TO HARDWARE REG TOO.
        CLI

; EXAMPLE OF INTERRUPT DISABLE

        SEI             ; TO AVOID CONFLICT WITH IRQ ...
        LDA     POKMSK  ; ... PROCESSOR WHICH ALTERS VAR.
        AND     #$FF-xx ; DISABLE BIT(S).
        STA     POKMSK
        STA     IRQEN   ; TO HARDWARE REGISTER TOO.
        CLI
```

Note that the O.S. IRQ service routine uses and alters POKMSK, so alterations to the variable must be done with interrupts inhibited. If done at the interrupt level there is no problem, as the I bit is already set; if done at a background level then the SEI and CLI instructions should be used as shown in the examples.

6.7.2 Setting interrupt and timer vectors

Because vertical blank interrupts are generally kept enabled so that the frame counter RTCLOK is maintained accurately, there is a problem with setting the VBLANK vectors (VVBLKI & VVBLKD) or the timer values (CDTMV1 through CDTMV5) directly. A VBLANK interrupt could occur when only one byte of the two byte value had been updated, leading to undesired consequences. For this reason, the SETVBV [E45F] routine is provided to perform the desired update in safe manner. The calling sequence is shown below:

```
A = update item indicator
    1 - 5 for timers 1 - 5.
    6 for immediate VBLANK vector VVBLKI.
    7 for deferred VBLANK vector VVBLKD.
X = MSB of value to store.
Y = LSB of value to store.

JSR    SETVBV

The A,X & Y registers may be altered.
The display list interrupt will always be enabled on
return.
```

side effects?

Note that it is possible that a vertical blank interrupt may be fully processed during a call to this routine.

When working with the system timers, the vectors for timers 1 & 2 and the flags for timers 3,4 & 5 should be set while the associated timer is equal to zero, then the timer should be set

to its (non-zero) value.

6.7.3 Stack content at interrupt vector points

The table below shows the stack content at every one of the RAM interrupt vector points:

VDSLST	[0200]	Display list	return, P
VVBLKI	[0222] *	VBLANK immed.	return, P, A, X, Y
CDTMA1	[0226]	System timer 1	return, P, A, X, Y, return
CDTMA2	[0228]	System timer 2	return, P, A, X, Y, return
VVBLKD	[0224] *	VBLANK defer.	return, P, A, X, Y
VIMIRQ	[0216] *	IRQ immediate	return, P
VSEROR	[020C] *	Serial out rdy.	return, P
VSERIN	[020A] *	Serial in rdy.	return, P
VSEROC	[020E] *	Serial out cmp.	return, P
VTIMR1	[0210]	POKEY timer 1	return, P
VTIMR2	[0212]	POKEY timer 2	return, P
VTIMR4	[0214]	POKEY timer 4	return, P
VKEYBD	[0208] *	Keyboard data	return, P
VPRSED	[0202]	Serial proceed	return, P
VINTER	[0204]	Serial interr.	return, P
VBREAK	[0206]	BRK instr.	return, P

Entries flagged with '*' are initialized by the operating system at power-up; changing these vectors will alter system performance if not done properly.

6.7.4 Miscellaneous considerations

The following paragraphs list a set of miscellaneous considerations for the writer of an interrupt service routine.

RESTRICTIONS ON CLEARING OF 'I' BIT

Display list, immediate vertical blank and system timer #1 routines should not clear the 6502 I bit. If the NMI leading to one of these routines occurred while an IRQ was being processed, then clearing the I bit will cause the IRQ to re-interrupt with unknown result.

The O.S. VBLANK processor carefully checks this condition after the stage 1 process and before the stage 2 process.

INTERRUPT PROCESS TIME RESTRICTIONS

If the serial I/O bus is being used, then any user defined interrupt routine plus the stage 1 VBLANK routine should not exceed 400 usec. SIO sets the CRITIC flag while serial bus I/O is in progress.

INTERRUPT DELAY DUE TO "WAIT FOR SYNC"

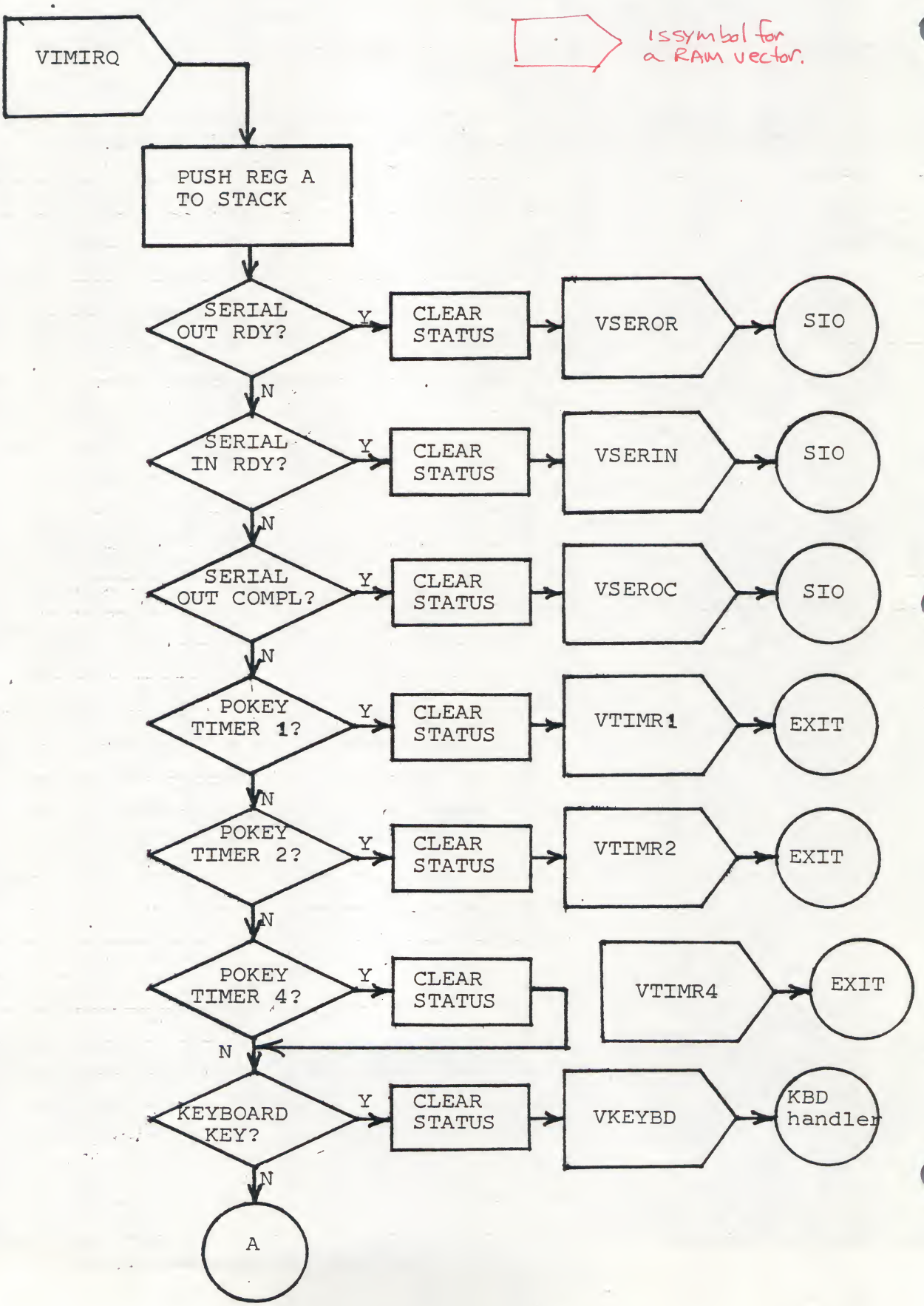
Whenever a key is read from the keyboard, the Keyboard handler sets WSYNC [D40A] repeatedly while generating the audible click on the console speaker. A problem occurs when interrupts are generated during the wait for sync period; the processing of such interrupts will be delayed by one horizontal scan line.

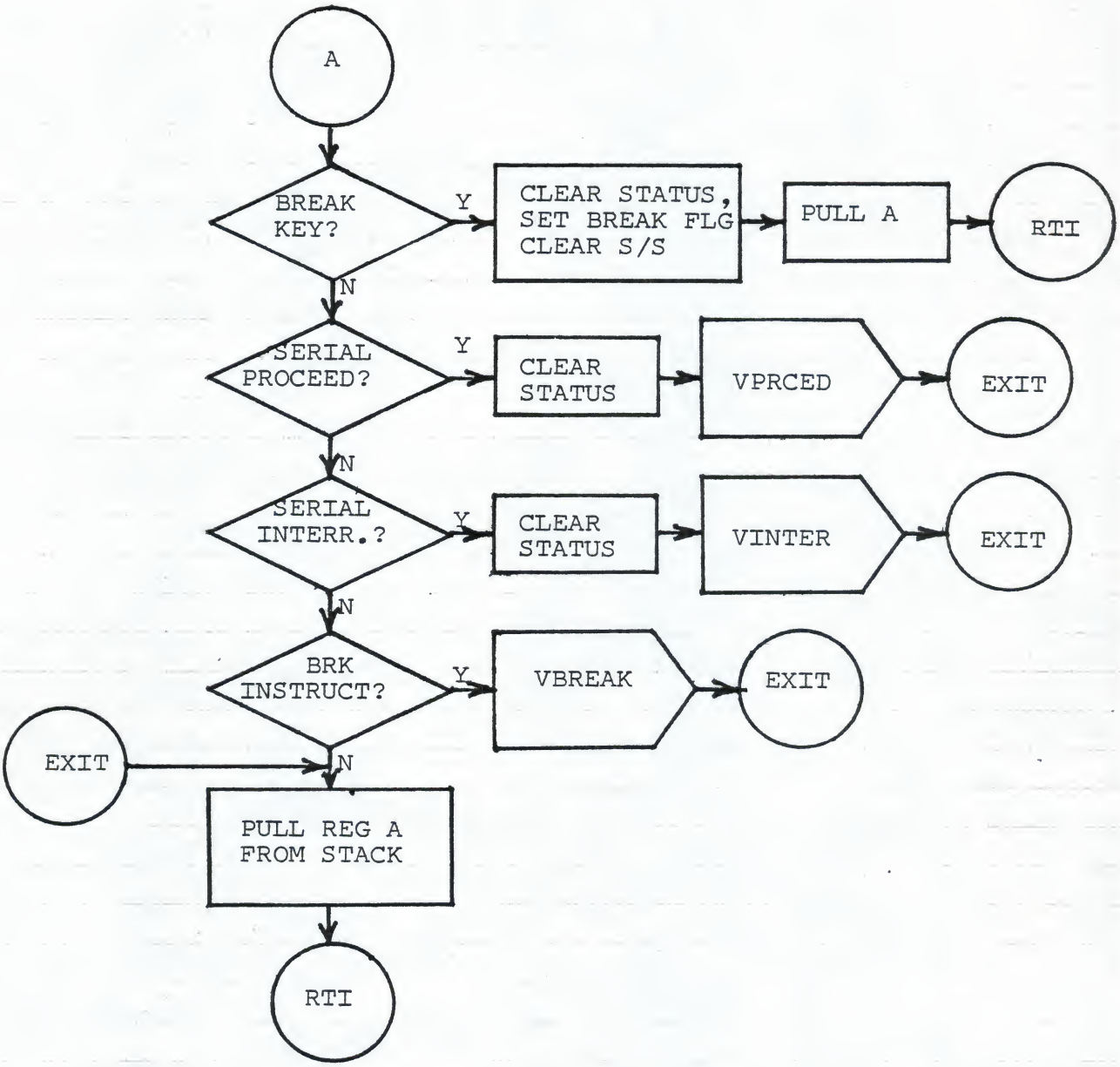
Since this condition cannot be prevented, a solution available to the user is to examine the line count VCOUNT [D40B] and delay interrupt processing by one line when no WSYNC delay has occurred.

6.8 Flowcharts

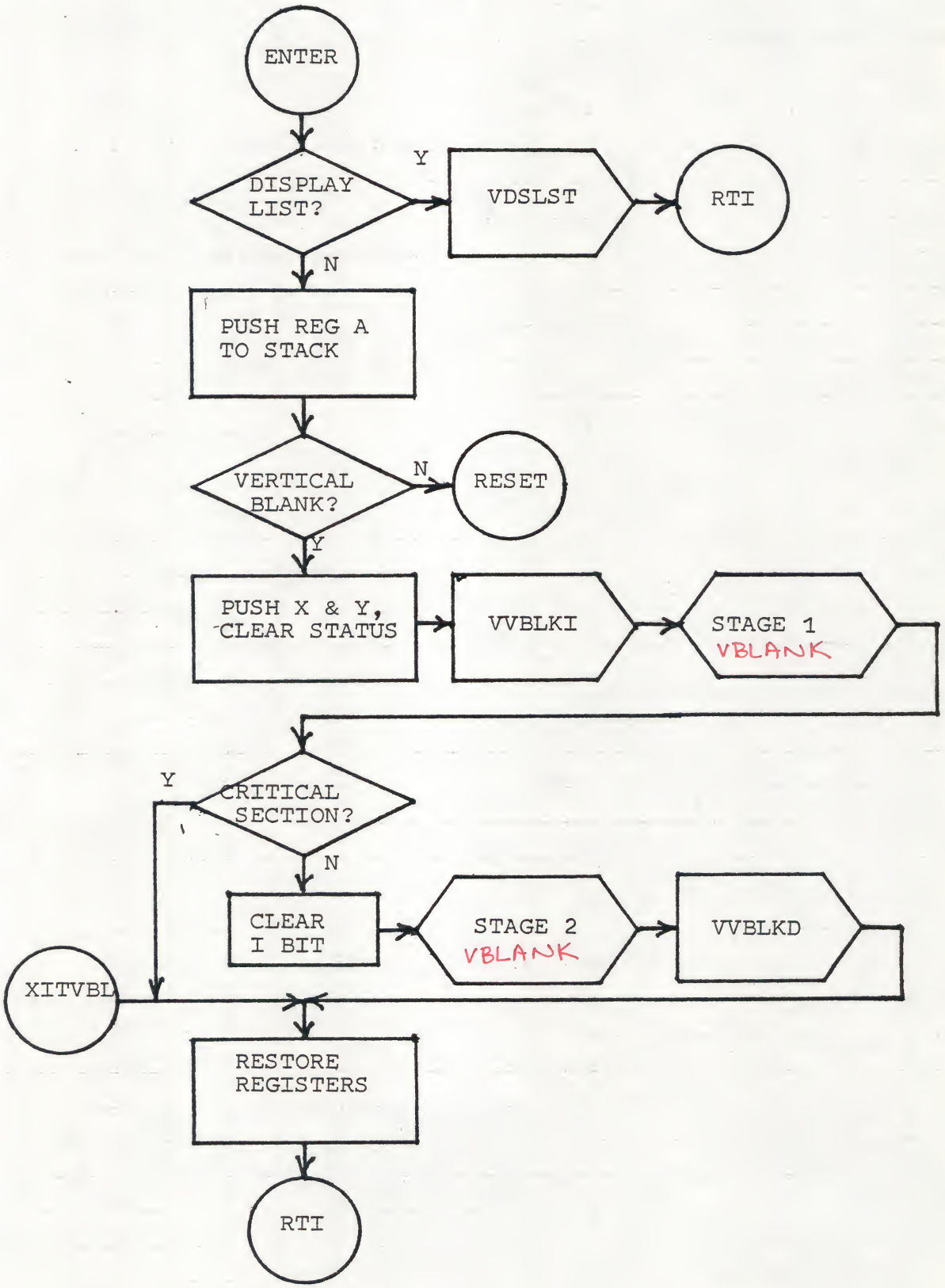
The following pages contain process flowcharts showing the main events that occur in the NMI and IRQ interrupt processes.

IRQ INTERRUPT PROCESS




A
BREAK KEY?
Y
CLEAR STATUS, SET BREAK FLG CLEAR S/S
PULL A
RTI
N
SERIAL PROCEED?
Y
CLEAR STATUS
VPRCED
EXIT
N
SERIAL INTERR.?
Y
CLEAR STATUS
VINTER
EXIT
N
BRK INSTRUCT?
Y
VBREAK
EXIT
EXIT
N
PULL REG A FROM STACK
RTI

NMI INTERRUPT PROCESS



7. System initialization

7.1 Overview

System initialization takes place automatically in two circumstances: power-up (also called coldstart) and the pressing of the RESET key (warmstart). In addition, there are vectors for these processes at E474 (RESET) and E477 (power-up) so that they may be user initiated.

The power-up initialization process is a superset of the RESET initialization process; power-up initializes both the O.S. and user RAM regions whereas RESET initializes only the O.S. RAM region. In both cases the outer level software initialization entry points are called to allow the application to initialize its own variables.

The remainder of section 7 will discuss the details of the power-up and RESET processes. Because they have many common functions (actually sharing common code), the power-up process will be explained first and then the RESET process will be explained in terms of its differences from the power-up process.

7.2 Power-up initialization (coldstart)

The functions listed below are performed, in the order shown, as part of the power-up initialization process:

1. The following 6502 processor functions are performed.

   IRQ interrupts are disabled using the SEI instruction.
   The decimal flag is cleared using the CLD instruction.
   The stack pointer is set to FF.

2. The warmstart flag WARMST [0008] is set to 0 (false).

3. A test is made to see if a diagnostic cartridge is in the "A" slot:

   Cartridge address BFFC = 00?
   The memory at BFFC is not RAM?
   Bit-7 of the byte at BFFD = 1?

If all of the above tests are true, then control is passed to the diagnostic cartridge via the vector at BFFE; no return is expected.

4. The lowest memory address containing non-RAM is determined by testing the first byte of every 4K "block" to see if the content can be complemented. If it can be complemented, then the original value is restored and testing continues; if it can't be complemented, it is assumed to be the first non-RAM address in the system. The MSB of the address is stored temporarily in TRAMSZ [0006].

5. Zero is stored to all of the hardware register addresses shown below (most of which aren't decoded by the hardware):

   D000 through D0FF
   D200 through D2FF
   D300 through D3FF

D400 through D4FF

6. RAM is cleared from location 0008 to the address determined in step 4 above.

7. The default value for the "non-cartridge" control vector DOSVEC [000A] is set to point to the blackboard routine. At the end of initialization, control is passed through this vector if a cartridge does not take control.

8. The coldstart flag COLDST [0244] is set to -1 (local use).

9. The screen margins are set; left margin = 2, right margin = 39 for a 38 character physical line (the maximum line size of 40 characters would be obtained by setting the margins to 0 & 39). The left margin is inset because many TV sets are manufactured such that the two leftmost columns of the video picture are not entirely visible on the screen.

10. The interrupt RAM vectors VDSLST [0200] through VVBLKD [0224] are initialized; see section 6.5 for the initialization values.

11. Portions of the O.S. RAM are set to their required non-zero values as shown below:

The BREAK key flag BRKKEY [0011] = -1 (false).

The top of memory pointer MEMTOP [02E5] = the lowest non-RAM address (from step 4); MEMTOP will be altered later when the Screen Editor is OPENed in step 15.

The bottom of memory pointer MEMLO [02E7] = 0700; MEMLO may be changed later if there is either a disk or cassette boot operation.

The following resident routines are called for initialization -- Screen Editor, Display handler, Keyboard handler, Printer handler, Cassette handler, Central I/O Monitor (CIO), Serial I/O Monitor (SIO) and the Interrupt processor.

The START key is checked, and if pressed, the cassette boot request flag CKEY [004A] is set.

12. 6502 IRQ interrupts are enabled using the CLI instruction.

13. The Device Table HATABS [031A] is initialized to point to the resident handlers. See section 9 for information relating to the device handler table.

14. The cartridge slot addresses for cartridges "B" and "A" are examined to determine if cartridges are inserted, if RAM does not extend into the cartridge address space.

If the content of location 9FFC is zero, then a JSR is executed through the vector at 9FFE, thus initializing cartridge "B". The cartridge is expected to return.

If the content of location BFFC is zero, then a JSR is executed

through the vector at BFFE, thus initializing cartridge "A". The cartridge is expected to return.

15. IOCB #0 is setup for an OPEN of the Screen Editor (E) and the OPEN is performed. The Screen Editor will use the highest portion of RAM for the screen and will adjust MEMTOP accordingly. If this operation should fail, the entire initialization process is repeated.

16. A delay is effected to assure that a VBLANK interrupt has occurred. This is done so that the screen will be established before continuing.

17. If the cassette boot request flag is set (see step 11 above), then a cassette boot operation is attempted. See section 10.3 for details of the cassette boot operation.

18. If any of the three conditions stated below exists, an attempt is made to boot from the disk.

There are no cartridges in the slots.

Cartridge "B" is inserted and bit-0 of 9FFD is 1.

Cartridge "A" is inserted and bit-0 of BFFD is 1.

See section 10.2 for details of the disk boot operation.

19. The coldstart flag COLDST is reset to indicate that the coldstart process went to completion.

20. The initialization process is now complete, and the controlling application is now determined via the remaining steps.

If there is an "A" cartridge inserted and bit-2 of BFFD is 1, then a JMP is executed through the vector at BFFA.

Else, if there is a "B" cartridge inserted and bit-2 of 9FFD is 1, then a JMP is executed through the vector at 9FFA.

Else a jump is executed through the vector DOSVEC which may point to the blackboard routine (default case), cassette booted software or disk booted software. DOSVEC may be altered by the booted software as explained in sections 10.2 and 10.3.

7.3 RESET initialization (warmstart)

The functions listed below are performed, in the order shown, as part of the RESET initialization process:

A. Same as power-up step 1.

B. The warmstart flag WARMST [0008] is set to -1 (true).

C. Same as power-up steps 3 through 5.

D. O.S. RAM is zeroed from locations 0200-03FF and 0010-007F.

E. Same as power-up steps 9 through 16.

F. If a cassette boot was successfully completed during the power-up initialization, then a JSR is executed through the vector CASINI [0002]. See section 10.3 for details of the cassette boot process.

G. Same as power-up step 18, except instead of booting the disk software, a JSR is executed through the vector DOSINI [000C] if the disk boot was successfully completed during the power-up initialization. See section 10.2 for details of the disk boot process.

H. Same as power-up steps 19 and 20.

Note that the initialization procedures and main entries for all software entities are executed at every RESET as well as at power-up (see steps 14, 17, 18, 20, F and G). If the user supplied initialization/startup code must behave differently in response to RESET than it does to power-up, then the warmstart flag WARMST [0008] should be interrrogated; WARMST = 0 means power-up entry, else RESET entry.

...scribes the BCD floating point package that is in the O.S. ROM in both the models 400 and 800.

8.1 Description

The floating point package maintains numbers internally as 6 byte quantities; a 5 byte (10 BCD digit) mantissa with a 1 byte exponent. BCD internal representation was chosen so that decimal division would not lead to the rounding errors typically found in binary representation implementations.

The package provides the following operations:

ASCII to F.P. conversion.
F.P. to ASCII conversion.
Integer to F.P. conversion.
F.P. to integer conversion.
F.P. add, subtract, multiply and divide.
F.P. logarithm, exponentiation and polynomial evaluation.
F.P. zero, load, store and move.

A floating point operation is performed by calling one of the provided routines (each at a fixed address in ROM) after having set one or more floating point pseudo registers in RAM. The result of the desired operation will also involve floating point pseudo registers. The primary pseudo registers are described below and their addresses given within the square brackets:

FR0 = 6 byte internal form of f.p. number [00D4].
FR1 = 6 byte internal form of f.p. number [00E0].
FLPTR = 2 byte pointer (lo,hi) to a f.p. number [00FC].
INBUFF = 2 byte pointer (lo,hi) to an ASCII text buffer [00F3].
CIX = 1 byte index, used as offset to buffer pointed to by INBUFF [00F2].
LBUFF = result buffer for the FASC routine [0580].

8.2 Functions/calling sequences

In the paragraphs that follow are the descriptions for all of the routines; unless specifically mentioned in the calling sequence, it is assumed that a pseudo register is not altered by a given routine. The numbers in square brackets [xxxx] are the ROM addresses of the routines.

ASCII to floating point conversion (AFP)

Function: This routine takes an ASCII string as input and produces a floating point number in internal form.

Calling sequence:

INBUFF = pointer to buffer containing the ASCII representation of the number.
CIX = the buffer offset to the first byte of the ASCII number.

(this is how the document we have really is; not a scanning mishap)

```
JSR     AFP [D800]
BCS     first byte of ASCII number is invalid

FR0 = floating point number.
CIX = the buffer offset to the first byte after the ASCII
      number.
```

Algorithm: The routine takes bytes from the buffer until it encounters a byte which cannot be part of the number. The bytes scanned to that point are then converted to a floating point number. If the first byte encountered is invalid, the carry bit is set as a flag.

Floating point to ASCII conversion (FASC)

Function: This routine converts a floating point number from internal form to its ASCII representation.

Calling sequence:

```
FR0 = floating point number.

JSR     FASC [D8E6]

INBUFF = pointer to the first byte of the ASCII number.
The last byte of the ASCII representation has the most
significant bit (sign bit) set; no EOL follows.
```

Algorithm: The routine converts the number from its internal floating point representation to a printable form (ATASCII). The pointer INBUFF will point to part of LBUFF, where the result is stored.

Integer to floating point conversion (IFP)

Function: This routine converts a two byte unsigned integer (0 to 65535) to floating point internal representation.

Calling sequence:

```
FR0 = integer (FR0+0 = LSB, FR0+1 = MSB).

JSR     IFP [D9AA]

FR0 = floating point representation of integer.
```

Floating point to integer conversion (FPI)

Function: This routine converts a positive floating point number from its internal representation to the nearest two byte integer.

Calling sequence:

FR0 = floating point number.

```
JSR     FPI [D9D2]
BCS     f.p. number is negative or >= 65535.5
```

FR0 = two byte integer (FR0+0 = LSB, FR0+1 = MSB).

Algorithm: The routine performs true rounding, not truncation, during the conversion process.

Floating point addition (FADD)

Function: This routine adds two floating point numbers and checks the result for out of range.

Calling sequence:

FR0 = floating point number.
FR1 = floating point number.

```
JSR     FADD [DA66]
BCS     out of range result.
```

FR0 = result of FR0 + FR1.
FR1 is altered.

Floating point subtraction (FSUB)

Function: This routine subtracts two floating point numbers and checks the result for out of range.

Calling sequence:

FR0 = floating point minuend.
FR1 = floating point subtrahend.

```
JSR     FSUB [DA60]
BCS     out of range result.
```

FR0 = result of FR0 - FR1.
FR1 is altered.

Floating point multiplication (FMUL)

Function: This routine multiplies two floating point numbers and checks the result for out of range.

Calling sequence:

FR0 = floating point multiplier.
FR1 = floating point multiplicand.

```
JSR     FMUL [DADB]
BCS     out of range result.
```

```
     FR0 = result of FR0 * FR1.
     FR1 is altered.
```

Floating point division (FDIV)

Function: This routine divides two floating point numbers and checks for division by zero and for result out of range.

Calling sequence:

```
     FR0 = floating point dividend.
     FR1 = floating point divisor.

     JSR       FDIV [DB28]
     BCS       out of range result or divisor is zero.

     FR0 = result of FR0 / FR1.
     FR1 is altered.
```

Floating point logarithms (LOG & LOG10)

Function: These routines take the natural or base 10 logarithms of a floating point number.

Calling sequence:

```
     FR0 = floating point number.

     JSR       LOG [DECD] for natural logarithm
or
     JSR       LOG10 [DED1] for base 10 logarithm
     BCS       negative number or overflow.

     FR0 = floating point logarithm.
     FR1 is altered.
```

Algorithm: Both logarithms are first computed as base 10 logarithms using a 10 term polynomial approximation; the natural logarithm is computed by dividing the base 10 result by the constant LOG10(e).

The logarithm of a number Z is computed as follows:

```
     F * (10 ** Y) = Z where 1 <= F < 10 (normalization).
     L = LOG10(F) by 10 term polynomial approximation.
     LOG10(Z) = Y + L.
     LOG(Z) = LOG10(Z) / LOG10(e).
```

Note: This routine does not return an error if the number input is zero; the LOG10 result in this case is approximately -129.5, which is not useful.

Floating point exponentiation (EXP and EXP10)

Function: This routine exponentiates.

Calling sequence:

```
     FR0 = floating point exponent (Z).

     JSR       EXP [DDC0] for e ** Z
or
     JSR       EXP10 [DDCC] for 10 ** Z
     BCS       overflow.

     FR0 = floating point result.
     FR1 is altered.
```

Algorithm: Both exponentials are computed internally as base 10, with the base e exponential using the identity:

e ** X = ~~EXP10~~ 10 ** (X * LOG10(e)).

The base 10 exponential is evaluated in two parts using the identity:

10 ** X = 10 ** (I + F) = (10 ** I) * (10 ** F) -- where I is the integer portion of X and F is the fraction.

The term 10 ** F is evaluated using a polynomial approximation, and 10 ** I is a straightforward modification to the floating point exponent.

Floating point polynomial evaluation (PLYEVL)

Function: This routine performs an n degree polynomial evaluation.

Calling sequence:

```
     X,Y = pointer (X = LSB) to list of f.p. coefficients (A(i))
           ordered from high order to low order.
     A = number of coefficients in list.
     FR0 = floating point independent variable (Z).

     JSR       PLYEVL [DD40]
     BCS       overflow or other error.

     FR0 = result of A(n)*Z**n + A(n-1)*Z**n-1 ... + A(1)*Z +
           A(0).
     FR1 is altered.
```

Algorithm: The polynomial P(Z) = SUM(i=0 to n) (A(i)*Z**i) is computed using the standard method shown below:

```
     P(Z) = (...(A(n)*Z + A(n-1))*Z + ... + A(1))*Z + A(0)
```

Clear FR0 (ZFR0)

Function: This routine sets the contents of pseudo register FR0 to all zeroes.

Calling sequence:

```
JSR      ZFR0 [DA44]

FR0 = zero.
```

Clear page zero floating point number (ZF1)

Function: This routine sets the contents of a zero page floating point number to all zeroes.

Calling sequence:

```
X = zero page address of f.p. number to clear.

JSR      ZF1 [DA46]

zero page f.p. number(X) = zero.
```

Load floating point number to FR0 (FLD0R and FLD0P)

Function: These routines load pseudo register FR0 with the floating point number specified by the calling sequence.

Calling sequences:

```
X,Y = pointer (X = LSB) to f.p. number.

JSR      FLD0R [DD89]
```

or

```
FLPTR = pointer to f.p. number.

JSR      FLD0P [DD8D]


FR0 = floating point number (in either case).
FLPTR = pointer to f.p. number (in either case).
```

Load floating point number to FR1 (FLD1R and FLD1P)

Function: These routines load pseudo register FR1 with the floating point number specified by the calling sequence.

Calling sequences:

As in prior description, except the result goes to FR1 instead of FR0. FLD1R [DD98] and FLD1P [DD9C].

Store floating point number from FR0 (FST0R and FST0P)

Function: These routines store the contents of pseudo register FR0 to the address specified by the calling sequence:

Calling sequence:

As in prior descriptions, except the floating point number is stored from FR0 rather than loaded to FR0. FST0R [DDA7] and FST0P [DDAB].

Move floating point number from FR0 to FR1 (FMOVE)

Function: This routine moves the floating point number in FR0 to pseudo register FR1.

Calling sequence:

```
JSR      FMOVE [DDB6]
```

FR1 = FR0 (FR0 remains unchanged).

8.3 Resource utilization

The floating point package uses the following RAM locations in the course of performing the functions described in this section:

00D4 through 00FF
057E through 05FF

If the floating package is not utilized, all of those locations are available for the user program.

8.4 Implementation details

Floating point numbers are maintained internally as 6 byte quantities, with 5 bytes (10 BCD digits) of mantissa and 1 byte of exponent. The mantissa is always normalized such that the most significant byte is non-zero (note "byte" and not "BCD digit").

The most significant bit of the exponent byte provides the sign for the mantissa, 0 for positive and 1 for negative. The remaining 7 bits of the exponent byte provide the exponent in excess 64 notation; the resulting number represents powers of 100 decimal (not powers of 10). A result of this storage format is that the mantissa holds 10 BCD digits when the value of the exponent is an even power of 10 and holds 9 BCD digits when the value of the exponent is an odd power of 10.

The implied decimal point is always to the immediate right of the first byte so that an exponent that is less than 64 indicates a number less than 1 and an exponent greater than or equal to 64 represents a number greater than or equal to 1.

Zero is represented by a zero mantissa and a zero exponent. In testing for a result from any of the standard routines, it is

sufficient to test either the exponent or the first mantissa byte for zero.

The absolute value of floating point numbers must be greater than 10**-98 and less than 10**+98 or be equal to zero. There is perfect symmetry between positive and negative numbers with the exception that negative zero is never generated.

Although the precision of all computations is maintained at 9 or 10 decimal digits, the accuracy is somewhat less for those functions involving polynomial approximations (logarithm and exponentiation). Also, the problems inherent in all floating point systems are present here; for example: subtracting two very nearly equal numbers, adding numbers of disparate magnitude, or successions of any operation will all result in a loss of significant digits. For some types of applications an analysis of the data range and the order of evaluation of expressions may be required.

The remainder of this section will give some examples of the internal representation of some floating point numbers as an aid to understanding the storage format. All numbers prior to this point have been expressed in decimal notation, but the examples will use hexadecimal notation (note that 64 decimal, the excess number of the exponent, is 40 when expressed in hexadecimal).

```
Number: +0.02 = 2 * 10**-2 = 2 * 100**-1
Stored: 3F 02 00 00 00 00  (f.p. exponent = 40 - 1)

Number: -0.02 = -2 * 10**-2 = -2 * 100**-1
Stored: BF 02 00 00 00 00  (f.p. exponent = 80 + 40 - 1)

Number: +37.0 = 3.7 * 10**1 = 37 * 100**0
Stored: 40 37 00 00 00 00  (f.p. exponent = 40 + 0)

Number: -4.60312486 * 10**11 = -46.03... * 100**5
Stored: C5 46 03 01 24 86  (f.p. exponent = 80 + 40 + 5)

Number: 0.0
Stored: 00 00 00 00 00 00  (special case)
```

9. Adding new device handlers/peripherals

This section describes the interface requirements for a non-resident device handler that is to be accessed via the Central I/O utility (CIO); further, the Serial bus I/O utility (SIO) interface is defined for those handlers which utilize the Serial I/O bus.

The I/O subsystem is organized with three levels of software between the user and the hardware. At the outer level is CIO, which performs the following functions:

- Logical device name to device handler mapping (on OPEN).
- I/O Control Block (IOCB) maintenance.
- Logical record handling.
- User buffer handling.

Below CIO are the individual device handlers, which perform the following functions:

- Device initialization on power-up and RESET.
- Device dependent support of OPEN and CLOSE commands.
- Byte at a time data input and output.
- Device dependent special operations.
- Device dependent command support.
- Device data buffer management.

At the bottom level (for Serial I/O bus peripheral handlers) is SIO, which performs the following functions:

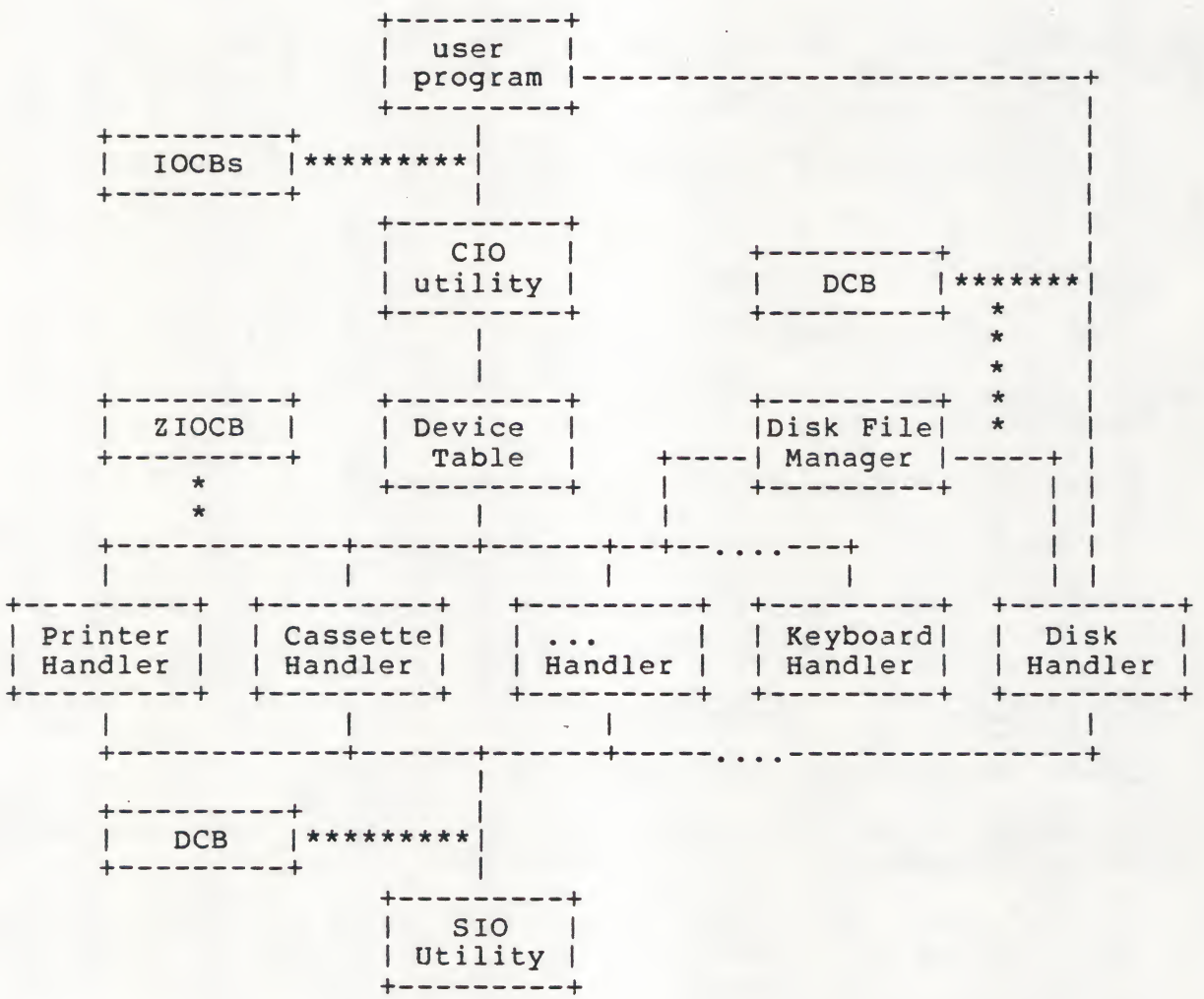
- Control of all Serial bus I/O, conforming to the bus protocol as described in section 9.4.
- Bus operation retries on errors.
- Return of unified error statuses on error conditions.

At each interface there is a separate control structure used for communication, as shown below:

User/CIO	I/O Control Block (IOCB)
CIO/Handler	Zero page IOCB (ZIOCB)
Handler/SIO	Device Control Block (DCB)

These relationships are shown graphically on the next page.

I/O SUBSYSTEM FLOW DIAGRAM



Where: ---- shows a control path.
**** shows the data structure required for a path.

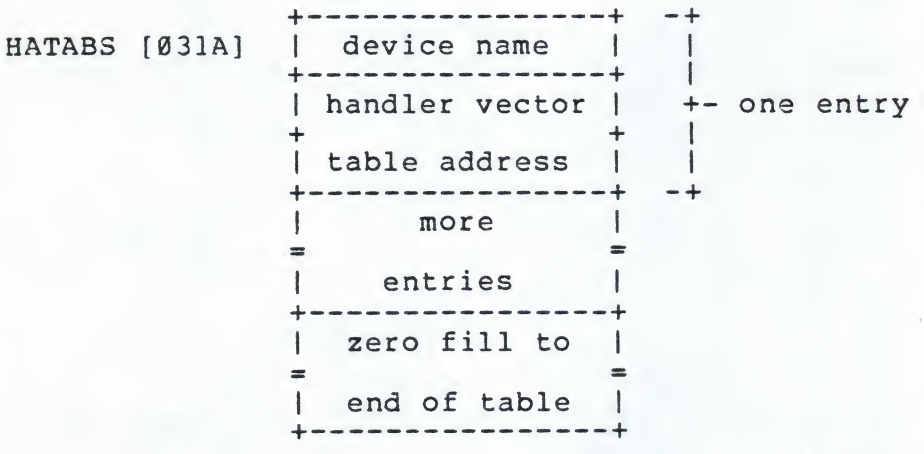
Note the following:

1. The Keyboard/Display/Screen Editor handlers don't use SIO.
2. The Disk handler is not callable directly from CIO.
3. The DCB is shown twice in the diagram.

9.1 Device Table

The Device Table is a RAM resident table that contains the single character device name (e.g. K, D, C, etc.) and the handler address for each of the handlers known to CIO. The table is initialized at power-up (and RESET) to contain entries for the following resident handlers: Keyboard (K), Display (S), Screen Editor (E), Cassette (C) and Printer (P). To install a new handler, some procedure must insert a Device Table entry after the table is initialized.

The table format is shown below:



The table is 38 bytes long and will hold a maximum of 12 entries, with the last two bytes being zero. CIO scans the table from the end to the beginning (high to low address); so, in the case of multiple occurrences of a device name, the entry nearest the end of the table will take precedence.

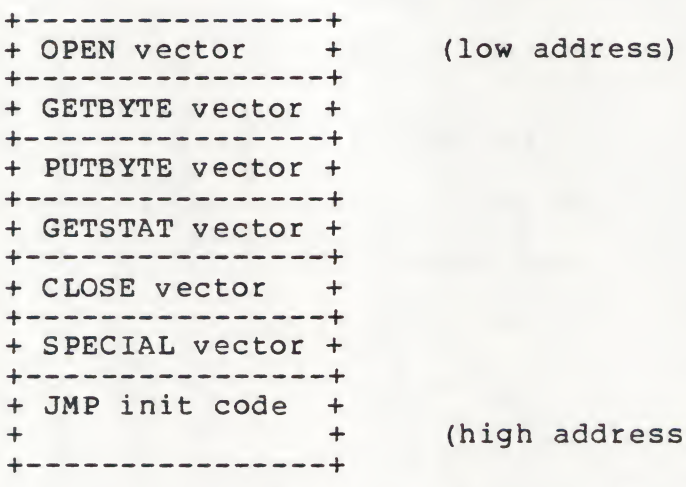
The device name for each entry is a single ATASCII character, and the handler address points to the handler's vector table, which will be described in the following section.

9.2 CIO/Handler interface

This section describes the interface between the Central I/O utility and the individual device handlers that are represented in the Device Table (as described in the preceding section).

9.2.1 Calling mechanism

Each handler has a vector table as shown below:



The Device Table entry for the handler points to the first byte of the vector table.

The first six entries in the table are vectors (lo,hi) which contain the address - 1 of the handler routine which handles the indicated function. The seventh entry is a 6502 JMP instruction to the handler initialization routine. CIO uses only the addresses contained in this table for handler entry; each user/CIO command translates to one or more calls to one of the handler entries defined in the vector table.

The vector table provides to CIO the handler addresses for certain fixed functions to be performed; but, in addition, operation parameters must be passed for most functions. Parameter passing is accomplished using the 6502 A, X and Y registers and an IOCB in page 0 named ZIOCB [0020]. In general, register A is used to pass data, register X contains the index to the originating IOCB and register Y is used to pass status information to CIO. The zero page IOCB is a copy of the originating IOCB; but in the course of processing some commands, CIO may alter the buffer address and buffer length parameters in ZIOCB (but not in the originating IOCB).

Reference Appendix B for the standard status byte values to be returned to CIO in register Y.

The following sections will describe the CIO/handler interface for each of the vectors in the handler vector table.

9.2.2 Handler initialization

This entry doesn't appear to have any function for non-resident handlers due to a bug in the current O.S. -- the Device Table is

cleared in response to both RESET and power-up, instead of just power- up, thus preventing this entry point from ever being called. The rest of this section discusses the intended, but not implemented, use of this entry point; conformation would be in order to allow compatibility with possible corrected versions of the O.S. in the future.

The entry was to have been called on all occurrences of power-up and RESET; the handler is to perform initialization of its hardware and RAM data so as to assure proper processing of all CIO commands that follow.

9.2.3 Functions supported

This section describes the functions associated with the first six vectors from the handler vector table. A brief, device independent, description of the CIO/handler interface and recommended actions are given for each function vector.

OPEN

This entry is called in response to an OPEN command to CIO; the handler is expected to validate the OPEN parameters and perform any required device initialization associated with a device OPEN.

At handler entry, the following parameters may be of interest:

X = index to originating IOCB.
Y = $92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).
ICBALZ/ICBAHZ [0024/0025] = address of device/filename specification.
ICAX1Z/ICAX2Z [002A/002B] = device specific information.

The handler will attempt to perform the indicated OPEN and will indicate the status of the operation by the value of the Y register. The responsibility for checking for multiple OPENs to the same device or file, where it is illegal, lies with the handler.

GETBYTE

This entry is called in response to a GET CHARACTERS or GET RECORD command to CIO. The handler is expected to return a single byte in the A register or return an error status in the Y register.

At handler entry, the following parameters may be of interest:

X = index to originating IOCB.
Y = $92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).

ICAX1Z/ICAX2Z [002A/002B] = device specific information.

The handler will obtain a data byte directly from the device or from a handler maintained buffer and return to CIO with the byte in the A register and the operation status in the Y register.

Handlers which do not have short timeouts associated with the reading of data (such as the Keyboard and Cassette handlers), must monitor the BREAK key flag BRKKEY [0011] and return with a status of $80 when a BREAK condition occurs. See section 4.5 E5 and section 12 for a discussion of BREAK key monitoring.

CIO checks for reads from device/files that have not been OPENed or OPENed for output only; the handler will not be called in those cases.

PUTBYTE

This entry is called in response to a PUT CHARACTERS or PUT RECORD command to CIO. The handler is expected to accept a single byte in the A register or return an error status in the Y register.

At handler entry, the following parameters may be of interest:

X = index to originating IOCB.
Y = $92 (status = function not implemented by handler).
A = data byte.

ICDNOZ [0021] = device number (1-4, for multiple device handlers).
ICAX1Z/ICAX2Z [002A/002B] = device specific information.

The handler will send the data byte directly to the device or to a handler maintained buffer and return to CIO with the operation status in the Y register. If a handler maintained buffer fills, the handler will send the buffered data to the device before returning to CIO.

CIO checks for writes to device/files that have not been OPENed or OPENed for input only; the handler will not be called in those cases.

Now that the normal operation of PUTBYTE has been defined, a special case must be added; any handler that will operate within the environment of the 8K BASIC language interpreter has a different set of rules. Because BASIC can call the handler PUTBYTE entry directly, without going through CIO, the zero-page IOCB (ZIOCB) may or may not have a relation to the PUTBYTE call; thus the handler must use the outer level IOCB to obtain any information that would normally be obtained from ZIOCB. Note also in this case that the OPEN protection normally provided by CIO is bypassed (i.e. PUTBYTE to a non-OPEN device/file and PUTBYTE to a read-only OPEN).

GETSTAT

This entry is called in response to a GET STATUS command to CIO. The handler is expected to return four bytes of status to memory or return an error status in the Y register.

At handler entry, the following parameters may be of interest:

```
X = index to originating IOCB.
Y = $92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device
                handlers).
ICBALZ/ICBAHZ [0024/0025] = address of device/filename
                            specification.
ICAX1Z/ICAX2Z [002A/002B] = device specific information.
```

The handler will get device status information from the device controller and put the status bytes in DVSTAT [02EA] through DVSTAT+3 and return to CIO with the operation status in register Y.

The IOCB need not be OPENed nor CLOSEd in order for the user to request CIO to perform a GET STATUS operation; the handler must check where there are restrictions. See section 5.2.3 for a discussion of the CIO actions involved with a GET STATUS operation using both OPEN and CLOSEd IOCBs, and note the impact of this on the use of the buffer address parameter.

CLOSE

This entry is called in response to a CLOSE command to CIO; the handler is expected to release any held resources that relate specifically to that device/filename, and for output files to: 1) send any data remaining in handler buffers to the device, 2) mark the end of file, and 3) update any associated directories, allocation maps, etc.

At handler entry, the following parameters may be of interest:

```
X = index to originating IOCB.
Y = $92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device
                handlers).
ICAX1Z/ICAX2Z [002A/002B] = device specific information.
```

The handler will attempt to perform the indicated CLOSE and will indicate the status of the operation by the value of the Y register.

CIO will deassign the associated IOCB after the handler returns, regardless of the operation status value.

SPECIAL

This handler entry is used to support all functions not handled by the other entry points, such as disk file RENAME, display

DRAW, etc. Specifically, if the IOCB command byte value is greater than $0D, then CIO will use the SPECIAL entry point. The handler must interrogate the command byte to determine if the requested operation is supported.

At handler entry, the following parameters may be of interest:

X = index to originating IOCB.
Y = $92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).
ICCOMZ [0022] = command byte.
ICBALZ/ICBALH [0024/0025] = buffer address.
ICBLLZ/ICBLHZ [0028/0029] = buffer length.
ICAX1Z/ICAX2Z [002A/002B] = device specific information.

The handler will perform the indicated operation, if possible, and return to CIO with the operation status in register Y.

The IOCB need not be OPENed nor CLOSEd in order for the user to request CIO to perform a SPECIAL operation; the handler must check where there are restrictions. See section 5.2.3 for a discussion of the CIO actions involved with a SPECIAL operation using both OPEN and CLOSEd IOCBs, and note the impact of this on the use of the buffer address parameter.

9.2.4 Error handling

Error handling has been simplified somewhat by having CIO handle outer level errors and having SIO handle Serial bus errors, leaving the handler to process the remaining errors. These errors include:

Out of range parameters.
BREAK key abort.
Invalid command.
Read after end of file.

The current handlers respond to errors using the following guidelines:

Keep the recovery simple (and therefore predictable & repeatable).

Do not interact directly with the user for recovery instructions.

Lose as little data as possible.

Make all attempts to maintain the integrity of file oriented device storage -- this involves the initial design of the structural elements as well as error recovery techniques.

9.2.5 Resource allocation

Non-resident handlers needing code and/or data space in RAM should use the techniques listed below, in order to assure non-

conflict with other parts of the O.S., including other non-resident handlers.

ZERO-PAGE RAM

There are no spare bytes of zero page RAM, and even if there were, there is no allocation scheme to support multiple program assignment of the spares. Therefore, the non-resident handler must save and restore the bytes of zero-page RAM it is going to use. The bytes to use must be chosen carefully, according to the following criteria:

The bytes may not be accessed by an interrupt routine.

The bytes may not be accessed by any non-interrupt code between the time the handler modifies the bytes and then restores the original values.

The simplist save/restore technique would utilize the stack in a manner similar to that shown below:

```
LDA     COLCRS          ; (for example)
PHA                     ; SAVE ON STACK.
LDA     COLCRS+1
PHA

LDA     HPOINT          ; HANDLER'S POINTER.
STA     COLCRS
LDA     HPOINT+1
STA     COLCRS+1

XXX     (COLCRS),Y      ; DO YOUR POINTER THING.

PLA                     ; RESTORE OLD DATA.
STA     COLCRS+1
PLA
STA     COLCRS
```

Note that for the example above, it would not be judicious to call the Display handler or the Screen Editor before restoring the original value of COLCRS, as COLCRS is a variable used by those routines.

NON-ZERO-PAGE RAM

Again, there is no allocation scheme to support the assignment of fixed regions of non-zero-page RAM to any specific process, so the handler has three choices:

1. Make a dynamic allocation at initialization time by altering MEMLO [02E7].

2. Include the variables with the handler for RAM resident handlers; this still involves altering MEMLO at the time the handler is booted.

3. If the handler is to be replacing one of the resident handlers by removing the resident handler's entry in the Device Table, then the new handler may use any RAM that the formerly resident handler would have used.

STACK SPACE

In normal situations there are no restrictions on the use of the stack by a handler; however, if the handler is planning on pushing more than a couple of dozen bytes to the stack, it should do a stack overflow test and always leave stack space for interrupt processing.

9.3 Handler/SIO interface

This section describes the interface between serial bus device handlers and the serial bus I/O utility (SIO). SIO completely handles all bus transactions following the device independent bus protocol defined in section 9.4. SIO is responsible for the following functions:

Bus data format and timing from computer end.

Error detection, retries and statuses.

Bus timeout.

Transfer of data between the bus and the caller's buffer.

9.3.1 Calling mechanism

SIO has a single entry point SIOV [E459] for all operations, and all parameters passed to SIO are contained in the Device Control Block (DCB) [0300], which contains the following bytes:

DEVICE BUS I.D. -- DDEVIC [0300]

The bus I.D. of the device is set by the handler prior to calling SIO (see Appendix I).

DEVICE UNIT # -- DUNIT [0301]

This byte indicates which of n units of a given device type to access and is set by the handler prior to calling SIO; in general this value comes from ICDNOZ. SIO will access the bus device whose address is equal to the value of DDEVIC plus DUNIT minus one (the lowest unit number is normally equal to one).

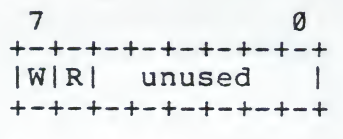
DEVICE COMMAND -- DCOMND [0302]

This byte is set by the handler prior to calling SIO and will be sent to the bus device as part of the command frame (see section 9.4.2 for a discussion of the command frame, and Appendix I for device command byte values).

DEVICE STATUS -- DSTATS [0303]

This byte is bi-directional; the handler will use it to indicate to SIO what to do after the command frame is sent and acknowledged, and SIO will use it to indicate to the handler the status of the requested operation.

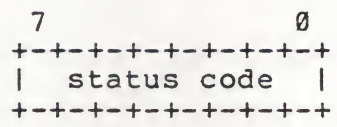
Prior to an SIO call:



Where: W,R = 0,0 indicates no data transfer is associated with the operation.
0,1 indicates a data frame is expected from the

device.
1,0 indicates a data frame is to be sent to the device.
1,1 is invalid.

After an SIO call:



See Appendix C for the possible SIO operation status codes.

HANDLER BUFFER ADDRESS -- DBUFLO/DBUFHI [0304/0305]

This two byte pointer is set by the handler and indicates the source or destination buffer for device data or status information.

DEVICE TIMEOUT -- DTIMLO [0306]

This byte is set by the handler and specifies the device timeout time in units of 64/60ths of a second. For example, a count of 6 specifies a timeout of 6.4 seconds.

BUFFER LENGTH/BYTE COUNT -- DBYTLO/DBYTHI [0308/0309]

This two byte count is set by the handler and indicates the number of data bytes to be transferred into or out of the buffer, for the current operation. This parameter is not required if the STATUS byte W and R bits are both zero, indicating that no data transfer is to take place.

AUXILLIARY INFORMATION -- DAUX1/DAUX2 [030A/030B]

These two bytes are set by the handler and are included in the bus command frame by SIO; they have device specific meanings.

9.3.2 Functions supported

SIO does not examine the COMMAND byte it sends to the device, as all bus transactions are expected to conform to a universal protocol which includes 3 forms. These forms are stated below (as seen from the computer):

Send command frame.

Send command frame and send data frame.

Send command frame and receive data frame.

The command form is selected purely by the values of the W and R bits in the STATUS byte as described earlier.

9.3.3 Error handling

SIO does the bulk of the error handling for the handler, in terms of Serial bus errors, as indicated below:

Bus timeout -- SIO provides a uniform command frame and data frame ACK byte timeout of 1/60th of a second - 0 / + 1/60th. The handler specifies the COMPLETE byte timeout value in DTIMLO as described earlier.

Bus errors -- SIO detects and reports UART overrun and framing errors; the sensing of these errors in any received byte will cause the entire associated frame to be considered bad.

Data frame checksum error -- SIO validates the checksum on all received data frames.

Invalid response from device -- In addition to the error conditions stated above, SIO checks that the ACK and COMPLETE responses are proper (ACK = $41 and COMPLETE = $43).

Bus operation retries -- SIO will attempt one complete command retry if the first attempt is not error free, where a complete command try consists of up to 14 attempts to send (and acknowledge) a command frame, followed by a single attempt to receive COMPLETE and possibly a data frame.

There is a bug in the retry logic for data writes, such that if the command frame is ACKed by the controller, but the data frame is not ACKed, then SIO will retry indefinitely.

Unified error status codes -- SIO provides device independent error codes as shown in Appendix C.

9.4 Serial I/O bus characteristics and protocol

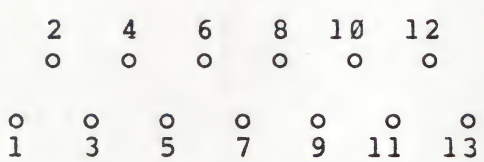
This section describes the electrical characteristics of the Atari 400/800 serial bus, the use of the bus to send bytes of data, the organization of the bytes as "frames" (records), and the overall command sequences which utilize frames and response bytes to provide computer/peripheral communication.

9.4.1 Hardware/electrical characteristics

The Atari 400/800 computer communicates with peripheral devices over a 19,200 baud asynchronous serial port. The serial port consists of a serial DATA OUT (transmission) line, a serial DATA IN (receiver) line and other miscellaneous control lines.

Data is transmitted and received as 8 bits of serial data (LSB sent first) preceded by a logic zero start bit and succeeded by a logic one stop bit. The serial DATA OUT is transmitted as positive logic (+4v = one/true/high, 0v = zero/false/low). The serial DATA OUT line always assumes its new state when the serial CLOCK OUT line goes high; CLOCK OUT then goes low in the center of the DATA OUT bit time.

An end view of the Serial bus connector at the computer or peripheral is shown below (the cable connectors would of course be a mirror image):



where: 1 = computer CLOCK IN.
2 = computer CLOCK OUT.
3 = computer DATA IN.
4 = GND.
5 = computer DATA OUT.
6 = GND.
7 = COMMAND-.
8 = MOTOR CONTROL.
9 = PROCEED-.
10 = +5v/READY.
11 = computer AUDIO IN.
12 = +12v.
13 = INTERRUPT-.

CLOCK IN is not used by the present O.S. and peripherals. This line can be used in future synchronous communications schemes.

CLOCK OUT is the serial bus clock. CLOCK OUT goes high at the start of each DATA OUT bit and returns to low in the middle of each bit.

DATA IN is the serial bus data line to the computer.

Pin 4 GND is the signal/shield ground line.

DATA OUT is the serial bus data line from the computer.

Pin 6 GND is the signal/shield ground line.

COMMAND- is normally high and goes low when a command frame is being sent from the computer.

MOTOR CONTROL is the cassette motor control line (high=on, low= off).

PROCEED- is not used by the present O.S. and peripherals (is this line tied high?).

+5v/READY indicates that the computer is turned on and ready. This line may also be used as a +5 volt supply of unknown current rating for Atari peripherals only.

AUDIO IN accepts an audio signal from the cassette.

+12V is a +12 volt supply of unknown current rating for Atari peripherals only.

INTERRUPT- is not used by the present O.S. and peripherals (is this line tied high?).

There are no pin reassignments made in the Serial bus cable, so pin 3, the computer's DATA IN line, is the peripheral's data output line; and similarly for pin 5.

Serial port electrical specifications

Peripheral input:

V1H = 2.0v min.
V1L = 0.4v max.

I1H = 20ua. max. @ V1H = 2.0v
I1L = 5ua. max. @ V1L = .4v

Peripheral output (open collector bipolar):

V0L = 0.4v max. @ 1.6 ma.
V0H = 4.5v min. with external 100Kohm pull-up.

Vcc/READY input:

V1H = 2.0v min. @ I1H = 1ma. max.
V1L = 0.4v max.
Input goes to logic zero when open.

9.4.2 Bus commands

The bus protocol specifies that all commands must originate from the computer, and that peripherals will present data on the bus only when commanded to. Every bus operation will go to completion before another bus operation is initiated (no overlap). An error detected at any point in the command sequence will abort the entire sequence.

A bus operation consists of the following elements:

Command frame from the computer.

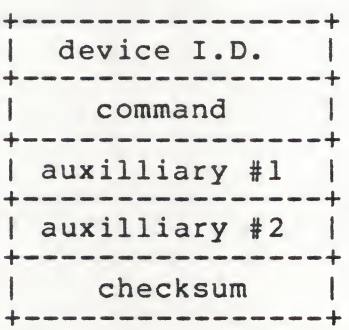
Acknowledgement (ACK) from the peripheral.

Optional data frame to or from the computer.

Operation complete (COMPLETE) from the peripheral.

COMMAND FRAME

The serial bus protocol provides for three types of commands: 1) data send, 2) data receive and 3) immediate (no data -- command only). There is a common element in all three types, a command frame consisting of five bytes of information sent from the computer while the COMMAND- line is held low. The format of the command frame is shown below:



The device I.D. specifies which of the serial bus devices is being addressed (see Appendix I for a list of device I.D.s).

The command byte contains a device dependent command (see Appendix I for a list of device commands).

The auxilliary bytes contain more device dependent information.

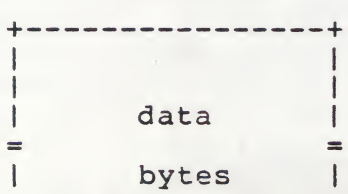
The checksum byte contains the arithmetic sum of the first four bytes (with the carry added back after every addition).

COMMAND FRAME ACKNOWLEDGE

The peripheral being addressed would normally respond to a command frame by sending an ACK byte ($41) to the computer; if there is a problem with the command frame, the peripheral should not respond.

DATA FRAME

Following the command frame (and ACK) may be an optional data frame which is formatted as shown below:



This data frame may originate at the computer or at the device controller, depending upon the command. Current device controllers expect fixed length data frames as does the computer, where the data frame length is a fixed function of the device type and command.

The checksum value in the data frame is the arithmetic sum of all of the frame data preceding the checksum, with the carry from each addition being added back (the same as for the command frame).

In the case of the computer sending a data frame to a peripheral, the peripheral is expected to send an ACK if the data frame is acceptable, and a NAK ($4E) or nothing if the data frame is unacceptable.

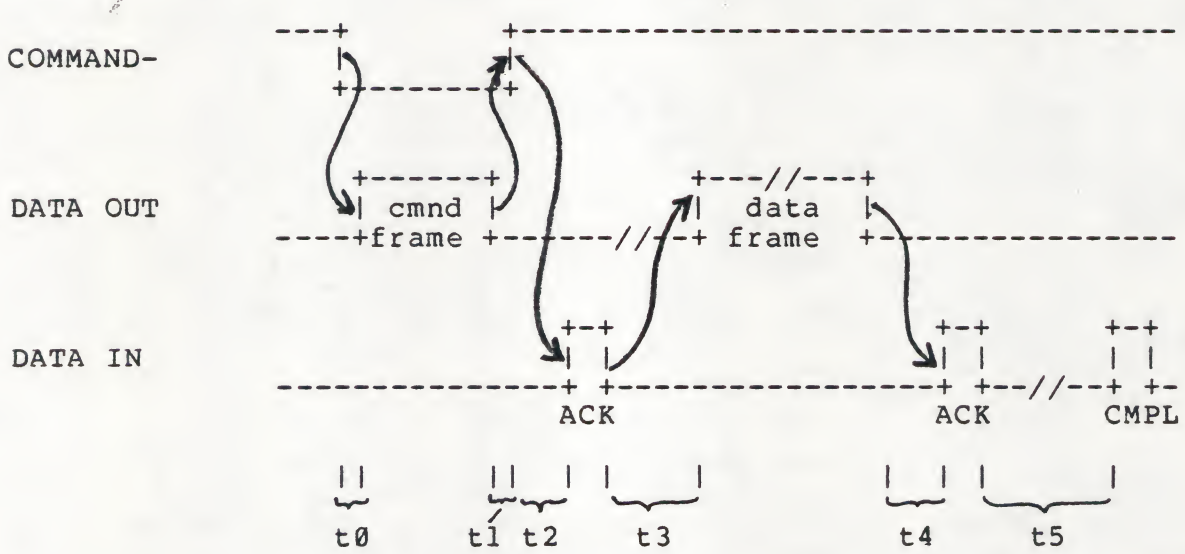
OPERATION COMPLETE

A peripheral is also expected to send an operation COMPLETE (CMPL) byte ($43) at the time the commanded operation is complete. The location of this byte in the command sequence for each command type is shown in the timing diagrams in section 9.4.3. If the operation cannot go to normal, error-free completion, the peripheral should respond with an ERROR byte ($45) instead of COMPLETE.

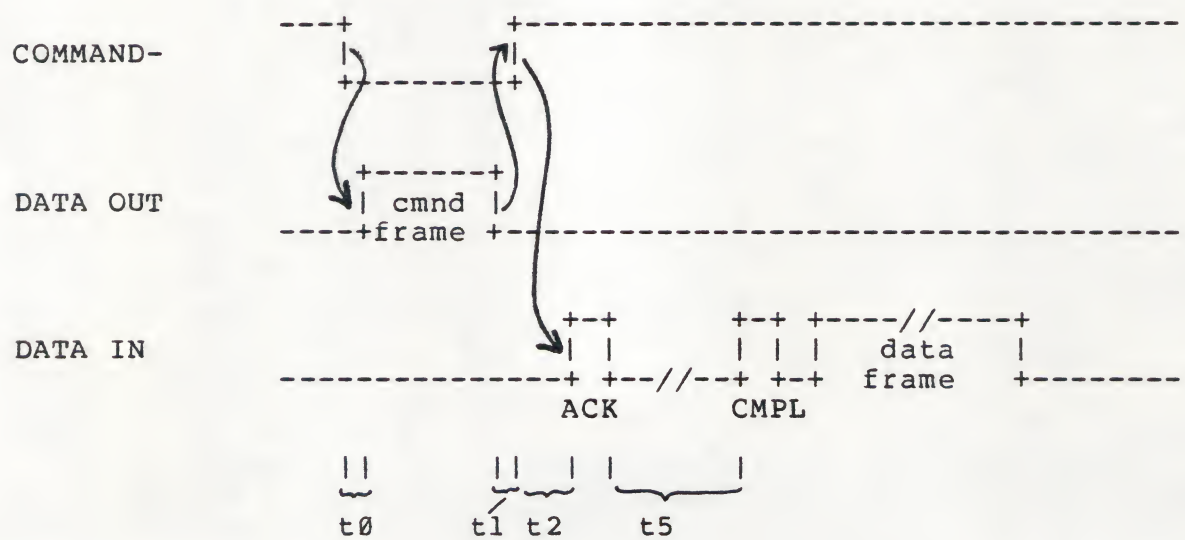
9.4.3 Bus timing

This section provides timing diagrams for the three types of command sequences: data send, data receive and immediate.

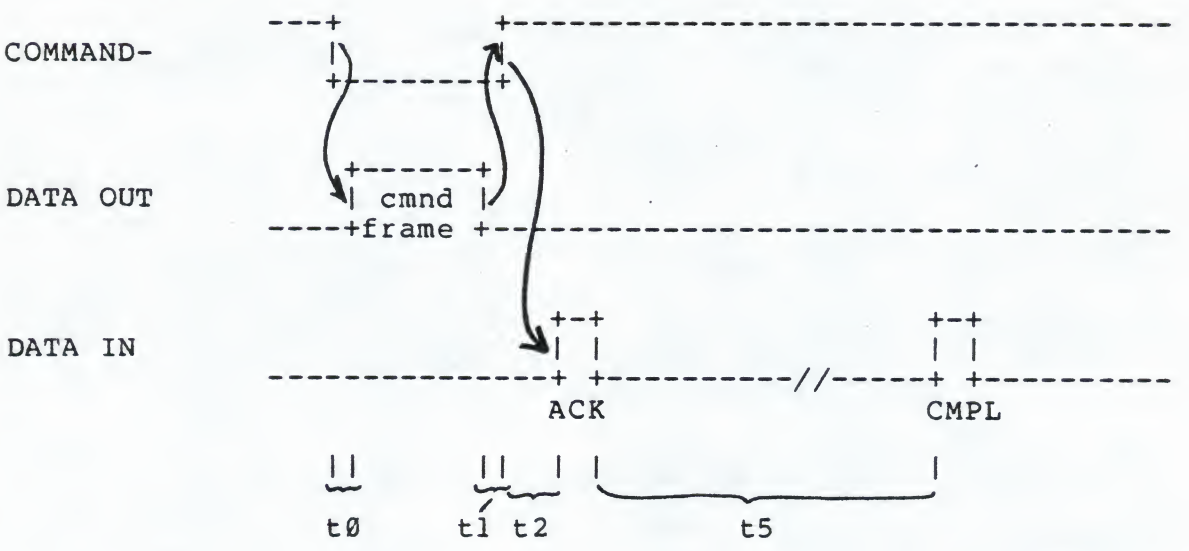
DATA SEND sequence:



DATA RECEIVE sequence:



IMMEDIATE sequence:



t0 is the delay between the lowering of COMMAND- and the transmission of the first byte of the command frame. The computer generates this delay.

computer t0 (min) = 750 usec.
computer t0 (max) = 1600 usec.

peripheral t0 (min) = ??
peripheral t0 (max) = ??

t1 is the delay between the transmission of the last bit of the command frame and the raising of the COMMAND- line. This delay is generated by the computer.

computer t1 (min) = 650 usec.
computer t1 (max) = 950 usec.

peripheral t1 (min) = ??
peripheral t1 (max) = ??

t2 is the delay between the raising of COMMAND- and the transmission of the ACK byte by the peripheral. The peripheral generates this delay.

computer t2 (min) = 0 usec.
computer t2 (max) = 16 msec.

peripheral t2 (min) = ??
peripheral t2 (max) = ??

t3 is the delay between the receipt of the last bit of the ACK byte and the transmission of the first bit of the data frame by the computer. The computer generates this delay.

computer t3 (min) = 1000 usec.
computer t3 (max) = 1800 usec.

peripheral t3 (min) = ??
peripheral t3 (max) = ??

t4 is the delay between the transmission of the last bit of the data frame and the receipt of the first bit of the ACK byte by the computer. The peripheral generates this delay.

computer t4 (min) = 850 usec.
computer t4 (max) = 16 msec.

peripheral t4 (min) = ??
peripheral t4 (max) = ??

t5 is the delay between the the receipt of the last bit of the ACK byte and the first bit of the COMPLETE byte by the computer. The peripheral generates this delay.

computer t5 (min) = 250 usec.
computer t5 (max) = 255 sec. (handler dependent)

peripheral t5 (min) = ??
peripheral t5 (max) = N/A

9.5 Handler environment

Non-resident handlers may be installed in at least three different manners:

1. As booted software from disk or cassette.

2. Resident in a cartridge (A or B).

3. Downloaded from a serial bus device.

This section will discuss the basic mechanisms for handler installation for these environments. In order to fully utilize the information in this section, you must have read and understood the following sections:

3.1 Program environments
4.1 RAM region
4.6 Memory dynamics
7 System initialization
9 Adding new device handlers/peripherals
10 Program environment and initialization

9.5.1 Bootable handler

The disk or cassette booted software will want to insert the handler's vector table pointer and name to the Device Table whenever the booted software's initialization entry point is entered (on power-up and RESET). Remember that both power-up and RESET clear the Device Table of all but the resident handler entries.

9.5.2 Cartridge resident handler

The cartridge software will want to insert the handler's vector table pointer and name to the Device Table whenever the cartridge's initialization entry point is entered (on power-up and RESET). Remember that both power-up and RESET clear the Device Table of all but the resident handler entries.

9.5.3 Serial bus downloadable handler

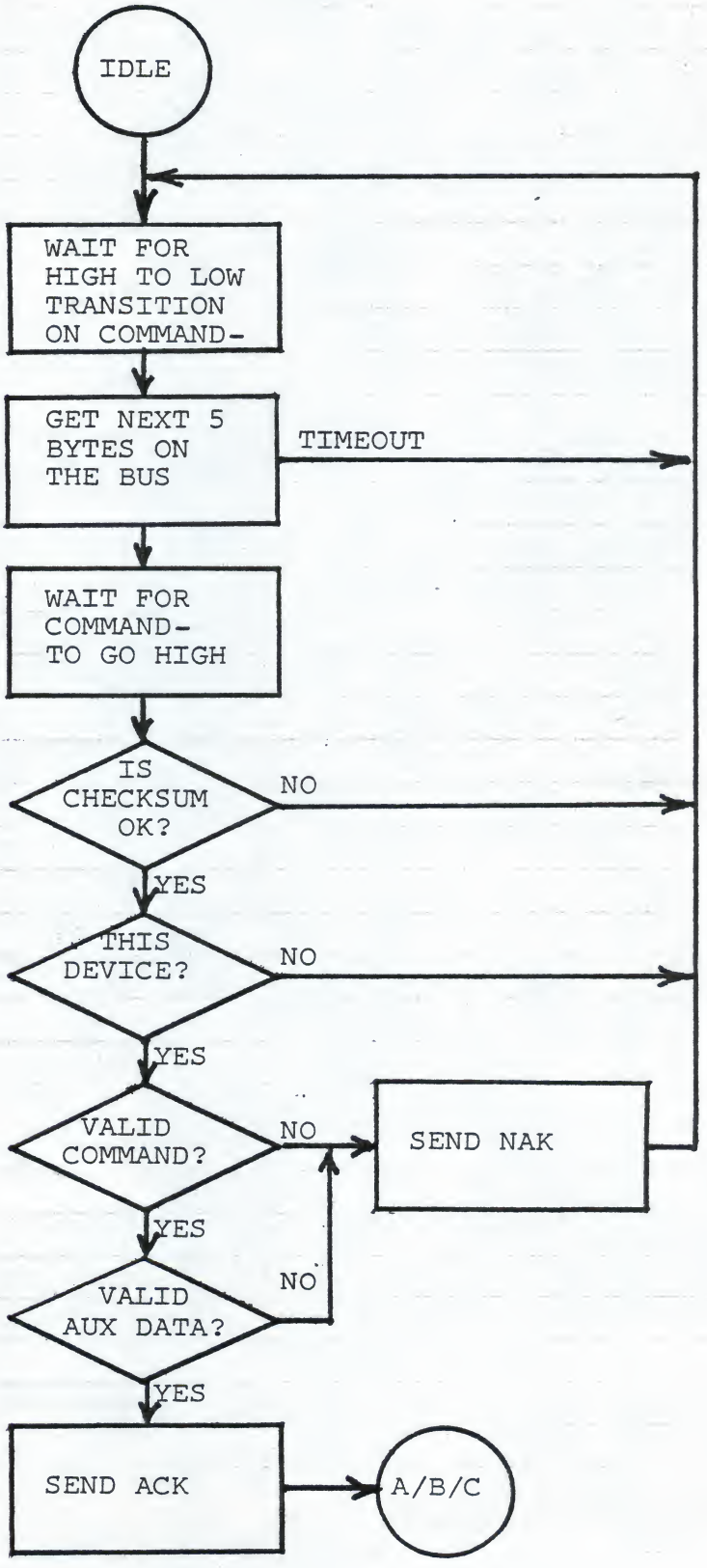
Get scoop from Rob and Scott on RS-232 peripheral.

9.5.4 Other

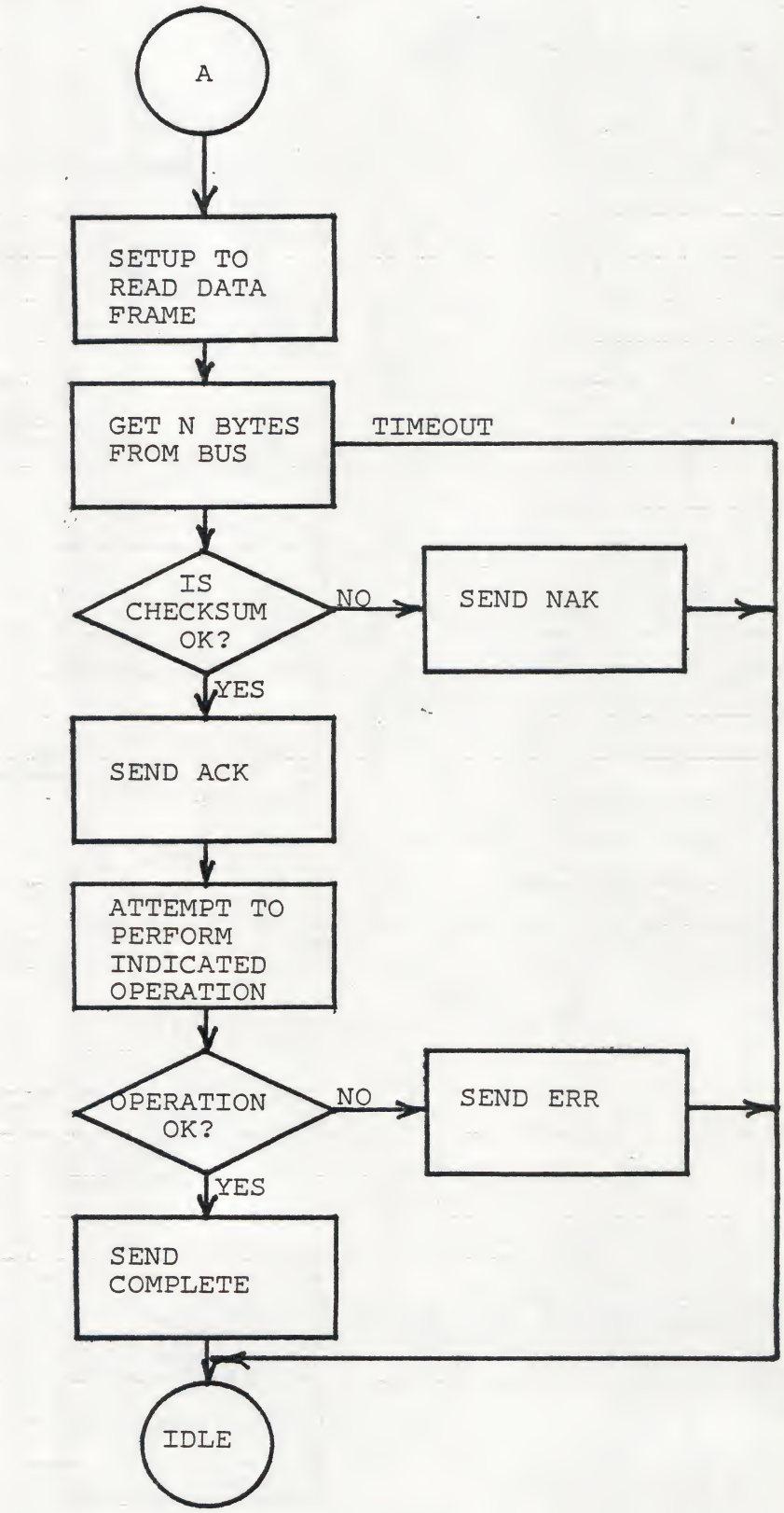
9.6 Flowcharts

The following pages contain process flowcharts showing the ~~SIO and~~ peripheral actions for the Serial bus command forms.

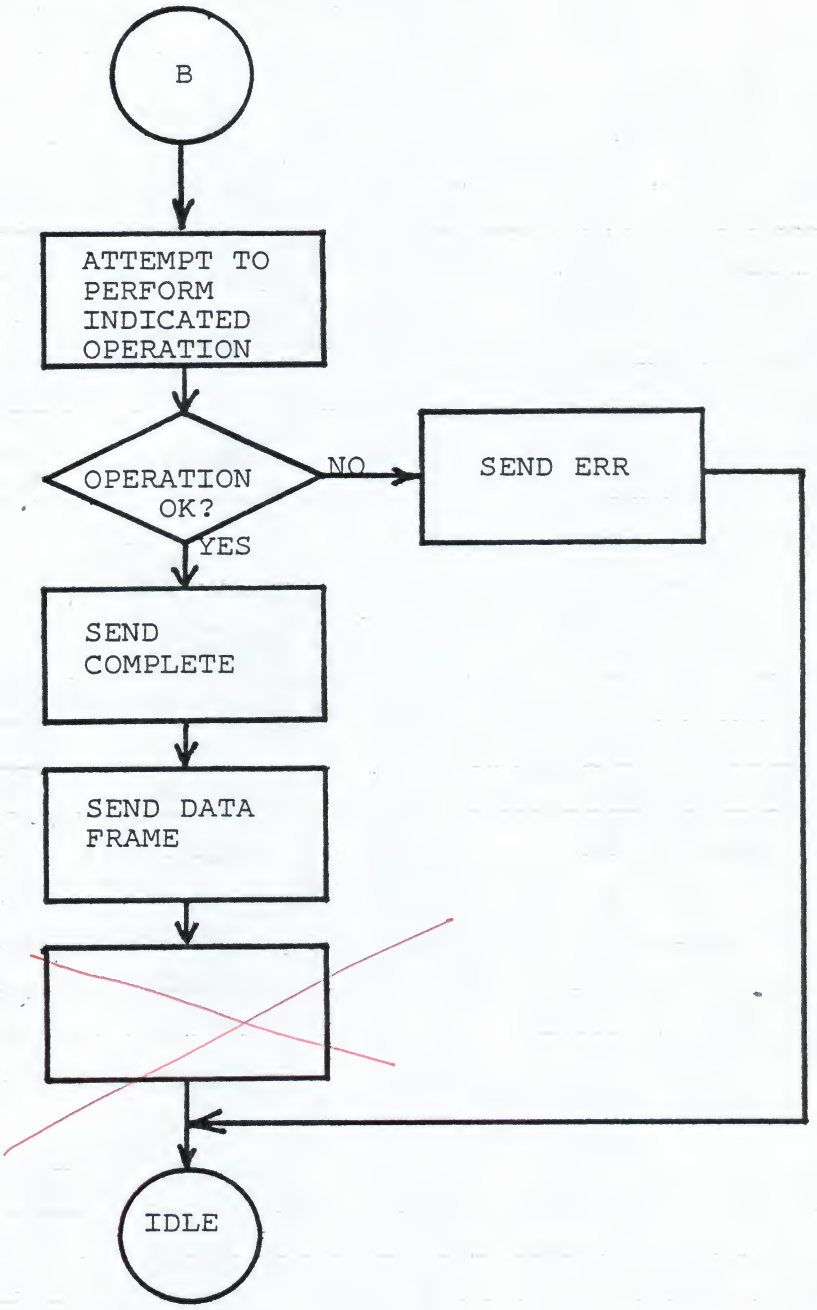
PERIPHERAL'S COMMAND FRAME PROCESSING



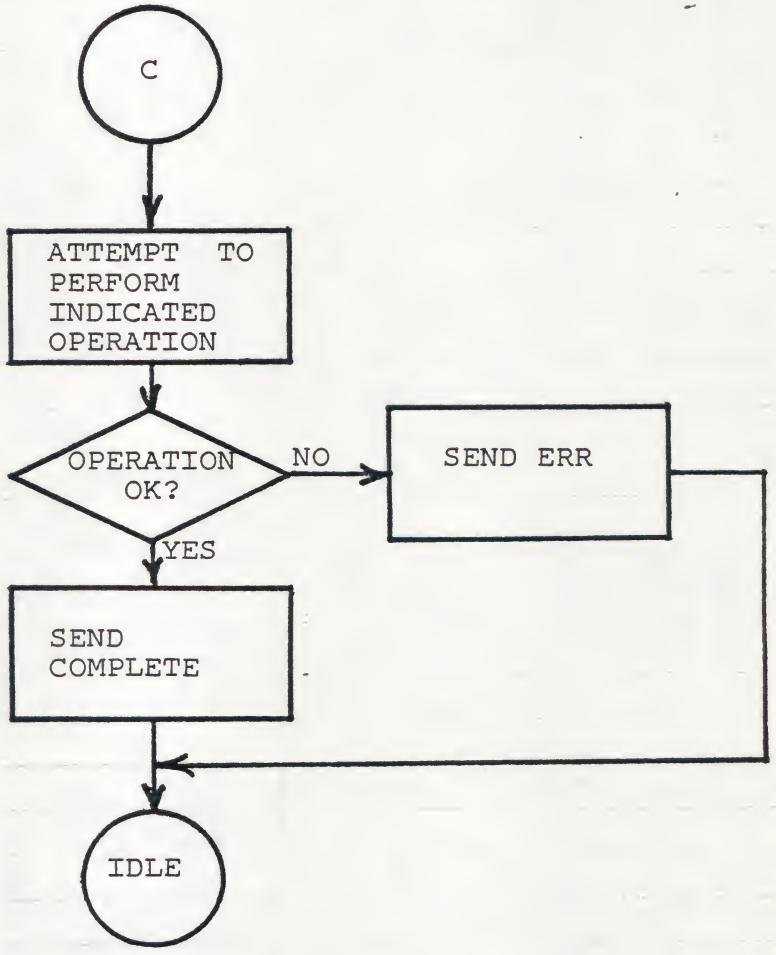
DATA FRAME TO PERIPHERAL



DATA FRAME TO COMPUTER



IMMEDIATE

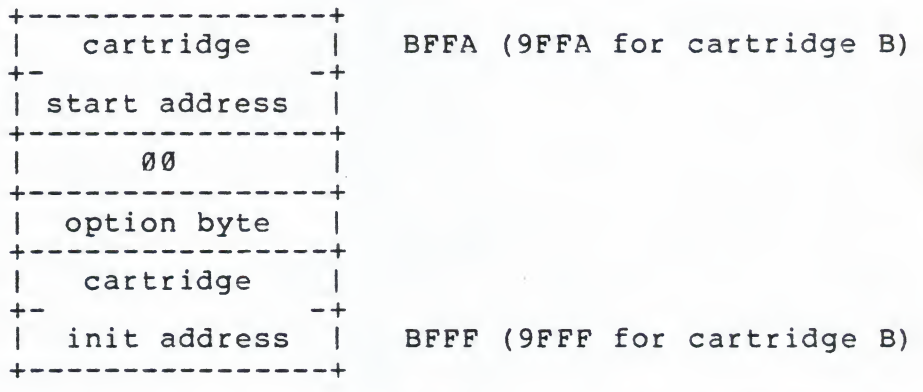

C
ATTEMPT TO PERFORM INDICATED OPERATION
OPERATION OK?
NO
SEND ERR
YES
SEND COMPLETE
IDLE

10. Program environment and initialization

This section discusses several of the different software environments that are possible using the O.S. Configurations other than those discussed here are possible, and a thorough understanding of the power-up and RESET processes (as described in section 7) will be necessary to evaluate other alternatives.

10.1 Cartridge

Most games (and some language processors) are supported via the cartridge environment. The cartridge resident software is in control of the system, sometimes using the O.S. and sometimes not. A cartridge can specify whether the disk is to be booted at power-up time, whether the cartridge is to provide the controlling software, or whether the cartridge is a special diagnostic cartridge. These options are specified by bits in the cartridge header, as shown below:



The byte of "00" is used to allow the O.S. to determine when a cartridge is inserted; locations BFFC and 9FFC will not read zero when there is neither RAM at those locations nor a cartridge inserted. RAM is differentiated from a cartridge by its ability to be altered.

The option byte has the following option bits:

Bit-0 = 0, then do not boot the disk.
1, then boot the disk.

Bit-2 = 0, then init but do not start the cartridge.
1, then init and start the cartridge.

Bit-7 = 0, then cartridge is not a diagnostic cartridge.
1, then cartridge is a diagnostic cartridge & control will be given to the cartridge before any of the O.S. is initialized (JMP (BFFE)).

The cartridge init address specifies the location to which the O.S. will JSR during all power-up and RESET operations. As a minimum, this vector should point to an RTS instruction.

The cartridge start address specifies the location to which the O.S. will JMP during all power-up and RESET operations, if bit-1 of the option byte is = 1. The application should examine the variable WARMST [0008] if RESET action is to be different than

power-up (WARMST will be zero on power-up and non-zero thereafter).

10.1.1 Cartridge without booted support package

A cartridge which does not specify the disk boot option and does not support the cassette boot possibility may use lower memory (from 0480 to the address in MEMTOP [02E5]) in any way it sees fit.

10.1.2 Cartridge with booted support package

A cartridge which does specify the disk boot option or does support the cassette boot possibility must use some care in its use of lower memory. The following regions are defined:

0480-06FF is always available to the cartridge.
MEMLO/MEMTOP region is always available to the cartridge.

10.2 Disk booted software

Software may be booted from the disk at power-up time in response to one of the following conditions:

Neither Cartridge A nor B is inserted.

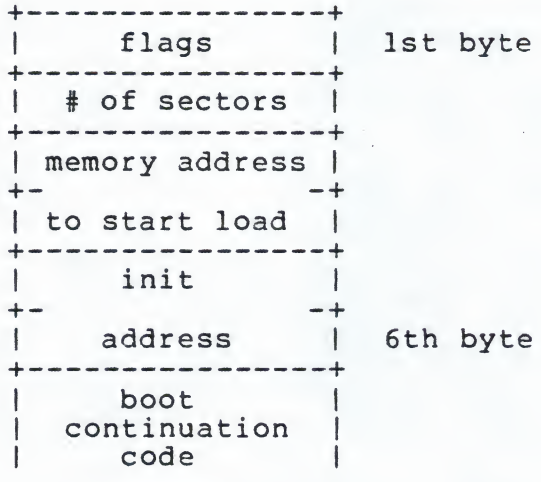
Cartridge A is inserted and has bit-0 if the option byte [BFFD] = 1.

Cartridge B is inserted and has bit-0 of its option byte [9FFD] = 1.

If any of these conditions are met, the O.S. will attempt to read the boot record from sector #1 of disk drive 1 and then transfer control to the software that was read in. The exact sequence of operations will be explained later in this section.

10.2.1 Disk boot file format

The key region of a disk boot file is the first 6 bytes, which are formatted as shown below:



The 1st byte is stored in DFLAGS [0240], but is otherwise unused.

The 2nd byte contains the number of 128 byte disk sectors to be read as part of the boot process (including the record containing this information). This number may range from 1 to 255, with 0 meaning 256.

The 3rd and 4th bytes contain the address (lo,hi) at which to start loading the first byte of the file.

The 5th and 6th bytes contain the address (lo,hi) to which the booter will transfer control after the boot process is complete and whenever the RESET key is pressed.

The Disk File Management System (FMS) has extra bytes assigned to its boot record, but this is a special case of the generalized disk boot and is discussed in section 5.3.6.

10.2.2 Disk boot process

The disk boot process is described step by step for a configuration in which no cartridge is installed. For the general case see section 7.

1. Read the first disk record to the cassette buffer [0400].

2. Extract information from the first 6 bytes:

   Save the flags byte to DFLAGS [0240,1].
   Save the # of sectors to boot to DBSECT [0241,1].
   Save the load address to BOOTAD [0242,2].
   Save the initialization address in DOSINI [000C,2].

3. Move the record just read to the load address specified.

4. Read the remaining records directly to the load area.

5. JSR to the load address+6 where a multi-stage boot process may continue; the carry bit will indicate the success of this operation (carry set = error, carry reset = success).

6. JSR indirectly through DOSINI for initialization of the application; the application will initialize and return.

7. JMP indirectly through DOSVEC to transfer control to the application.

Pressing the RESET key after the application is fully booted will cause steps 6 & 7 to be repeated.

Regarding step 5 -- After the initial boot process is complete, the booter will transfer control to the 7th byte of the first record; at this point the software should continue the boot process, if it is a multi-stage boot. The value of MEMLO [02E7], which should point to the first free RAM location beyond the software just booted, should be established by the booted software as shown below:

```
LDA     #END+1          ; SETUP LSB.
STA     MEMLO
STA     APPMHI
LDA     #END+1/256      ; SETUP MSB.
STA     MEMLO+1
STA     APPMHI+1
```

If the booted software is to take control of the system at the end of the boot operation, the vector DOSVEC [000A] must be setup by the application at this time; DOSVEC points to the restart entry for the booted application. If the booted software is not to take control, then DOSVEC should remain unchanged.

```
LDA     #RESTRT         ; RESTART LSB.
STA     DOSVEC
LDA     #RESTRT/256
STA     DOSVEC+1
```

Regarding step 6 -- The initialization point is entered on every RESET and power-up; internal initialization may take place here. For controlling applications initialization may also be deferred until step 7.

10.2.3 Sample disk bootable program listing

Shown below is a skeletal program which can be booted from the disk and which retains control when it is entered.

```
; THIS IS THE START OF THE PROGRAM FILE.

PST=    $0700                   ; (OR SOME OTHER LOCATION).
*=      PST                     ; (.ORG).


; THIS IS THE DISK BOOT CONTROL INFORMATION.

        .BYTE   0               ;
        .BYTE   PND-PST+127/128 ; NUMBER OF RECORDS.
        .WORD   PST             ; MEMORY ADDRESS TO START LOAD.
        .WORD   PINIT           ; PROGRAM INIT.

; THIS IS THE START OF THE BOOT CONTINUATION.

        LDA     #PND            ; ESTABLISH LOW MEMORY LIMITS.
        STA     MEMLO
        STA     APPMHI
        LDA     #PND/256
        STA     MEMLO+1
        STA     APPMHI+1

        LDA     #RESTRT         ; ESTABLISH RESTART VECTOR.
        STA     DOSVEC
        LDA     #RESTRT/256
        STA     DOSVEC+1

        CLC                     ; SET FLAG FOR SUCCESSFUL BOOT.
        RTS

; APPLICATION INITIALIZATION ENTRY POINT.

PINIT   RTS                     ; NOTHING TO DO HERE FOR ...
                                ; ... CONTROLLING APPLICATION.

; THE MAIN BODY OF THE PROGRAM FOLLOWS.

RESTRT=*

; THE MAIN BODY OF THE PROGRAM ENDS HERE.

PND=    *                       ; 'PND' = NEXT FREE LOCATION.
        .END
```

10.2.4 Program and procedure to create disk boot files

This section provides a procedure that may be used to make bootable files on disks. The procedure given is not the only one possible, and no claims are made as to its elegeance. The dialogue shown assumes that one is logged onto the PDP-11/34

computer from one of the development systems in the laboratories and is using LNBUG 2.0. A Model 400/800 with disk is required.

User: OSL <cr>

Comp: loads the operating system.

User: DLOAD BOOTDY <cr>

Comp: loads the boot file maker.

User: <CTRL-P> go to LNBUG control.
X <cr>

LNBG: responds with LNBUG prompt.

User: put a formatted disk in the drive.

User: E477G <cr> starts O.S. and initializes mem.

LNBG: responds with LNBUG prompt in response to BRK in 'BOOTDY'.

User: R verify BRK address.

User: $ <cr> <cr> returns to PDP-11/34 control.

Comp: . PDP-11 prompt.

User: DLOAD xxxxx <cr> xxxxx = name of application file.

Comp: loads the application file.

User: <CTRL-P> go to LNBUG control.
X <cr>

LNBG: responds with LNBUG prompt.

User: B001G<cr> resume 'BOOTDY'.

User: wait for completion of the disk file write.

LNBG: responds with LNBUG prompt in response to BRK in 'BOOTDY'.

User: R verify BRK address.

User: to write another boot file, type B001G <cr>.

Shown below is a listing of the program referred to as 'BOOTDY' in the procedure above:

```
; THIS PROGRAM WRITES A SINGLE "FILE" TO THE DISK AND IS
; USED IN CONJUNCTION WITH A PROCEDURE TO MAKE DISK
; BOOTABLE FILES.  THE FOLLOWING TWO SYMBOLS MUST BE EQUATED
; USING THE MEMORY LIMITS OF THE PROGRAM TO BE COPIED:
;
;     'PST' = PROGRAM START ADDRESS (SEE SAMPLE PROGRAM).
;     'PND' = PROGRAM END ADDRESS (SEE SAMPLE PROGRAM).

SECSIZ=128                      ; DISK SECTOR SIZE.
```

```
PST=    $0700
PND=    $1324
FLEN=   PND-PST+SECSIZ-1/SECSIZ ; # OF SECTORS IN FILE.

*=      $B000                   ; THIS PROGRAM'S ORIGIN.

BOOTB   BRK                     ; *** LOAD APPLICATION ***

; SETUP DEVICE CONTROL BLOCK FOR DISK HANDLER CALL

        LDA     #FLEN           ; # OF SECTORS TO WRITE.
        STA     COUNT

        LDA     #1              ; DISK DRIVE #1.
        STA     DUNIT

        LDA     #'W             ; SETUP FOR WRITE WITH CHECK.
        STA     DCOMND

        LDA     #PST            ; POINT TO START OF APPLIC. PROG.
        STA     DBUFLO
        LDA     #PST/256
        STA     DBUFHI

        LDA     #01             ; SETUP STARTING SECTOR # = 0001.
        STA     DAUX1
        LDA     #00
        STA     DAUX2

; NOW WRITE THE FILE ONE SECTOR AT A TIME.

BOT010  JSR     DSKINV          ; WRITE ONE SECTOR.
        BMI     DERR            ; ERROR.

        LDA     DBUFLO          ; INCREMENT MEMORY ADDRESS.
        CLC
        ADC     #SECSIZ
        STA     DBUFLO
        LDA     DBUFHI
        ADC     #0
        STA     DBUFHI

        INC     DAUX1           ; INCREMENT SECTOR #.
        BNE     BOT020
        INC     DAUX2

BOT020  DEC     COUNT           ; MORE SECTORS TO WRITE?
        BNE     BOT010          ; YES.

        BRK                     ; STOP WHEN DONE.

DERR    BRK                     ; STOP ON ERROR.

COUNT   *=*+1                   ; SECTOR COUNT.

; THIS IS THE CARTRIDGE HEADER

*=      $BFF9                   ; "A" CARTRIDGE.

INIT    RTS
```

```
.WORD   BOOTB
.BYTE   0,4
.WORD   INIT

.END
```

10.3 Cassette booted software

Software may be booted from the cassette at power-up time in much the same way as from the disk, as described in the previous section. The following requirements must be met in order to boot from the cassette:

The operator must be pressing the START key as power is applied to the system.

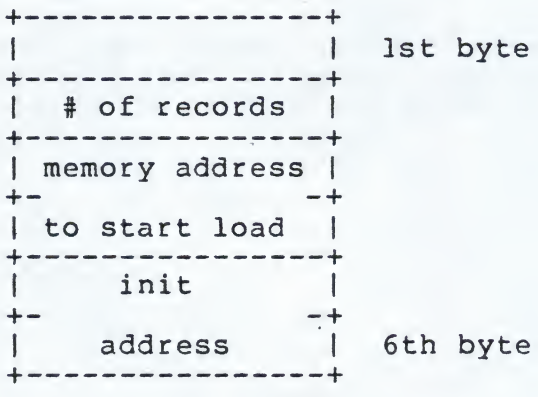
A cassette tape with a proper boot format file must be installed in the cassette drive.

When the operator is given the audio prompt by the cassette handler he must press the RETURN key.

If all of these conditions are met, the O.S. will read the boot file from the cassette and then transfer control to the software that was read in. The exact sequence of operations will be explained later in this section.

10.3.1 Cassette boot file format

The key region of a cassette boot file is the first 6 bytes, which are formatted as shown below:



The 1st byte is not used by the cassette boot process.

The 2nd byte contains the number of 128 byte cassette records to be read as part of the boot process (including the record containing this information). This number may range from 1 to 255, with 0 meaning 256.

The 3rd and 4th bytes contain the address (lo,hi) at which to start loading the first byte of the file.

The 5th and 6th bytes contain the address (lo,hi) to which the booter will transfer control after the boot process is complete and whenever the RESET key is pressed.

10.3.2 Cassette boot process

The cassette boot process is described step by step for a configuration in which no cartridge is installed and no disks are attached. For the general case see Section 7.

1. Read the first cassette record to the cassette buffer.

2. Extract information from the first 6 bytes:

   Save the # of records to boot.
   Save the load address.
   Save the initialization address in CASINI [0002].

3. Move the record just read to the load address specified.

4. Read the remaining records directly to the load area.

5. JSR to the load address+6 where a multi-stage boot process may continue; the carry bit will indicate the success of this operation (carry set = error, carry reset = success).

6. JSR indirectly through CASINI for initialization of the application; the application will initialize and return.

7. JMP indirectly through DOSVEC to transfer control to the application.

Pressing the RESET key after the application is fully booted will cause steps 6 & 7 to be repeated.

Regarding step 5 -- After the initial boot process is complete, the booter will transfer control to the 7th byte of the first record; at this point the software should continue the boot process (if it is a multi-stage boot) and then stop the cassette drive, which due to a system bug will still be running, using the following instruction sequence:

```
LDA     #$3C
STA     PACTL [D302]
```

The application should then set a value in MEMLO [02E7] which points to the first free RAM location beyond the software just booted, as shown below:

```
LDA     #END+1          ; SETUP LSB.
STA     MEMLO
STA     APPMHI
LDA     #END+1/256      ; SETUP MSB.
STA     MEMLO+1
STA     APPMHI+1
```

If the booted software is to take control of the system at the end of the boot operation, the vector DOSVEC [000A] must be setup by the application at this time; DOSVEC points to the restart entry for the booted application. If the booted software is not to take control, then DOSVEC should remain unchanged.

```
LDA     #RESTRT         ; RESTART LSB.
STA     DOSVEC
LDA     #RESTRT/256
STA     DOSVEC+1
```

Regarding step 6 -- The initialization point is entered on

every RESET and power-up; internal initialization may take place here. For controlling applications initialization may also be deferred until step 7.

10.3.3 Sample cassette bootable program listing

Shown below is a skeletal program which can be booted from the cassette and which retains control when it is entered.

```
; THIS IS THE START OF THE PROGRAM FILE.

PST=    $0700                   ; (OR SOME OTHER LOCATION).
*=      PST                     ; (.ORG).


; THIS IS THE CASSETTE BOOT CONTROL INFORMATION.

        .BYTE   0               ; (DOESN'T MATTER).
        .BYTE   PND-PST+127/128 ; NUMBER OF RECORDS.
        .WORD   PST             ; MEMORY ADDRESS TO START LOAD.
        .WORD   PINIT           ; PROGRAM INIT.

; THIS IS THE START OF THE BOOT CONTINUATION.

        LDA     #$3C            ; STOP THE CASSETTE.
        STA     PACTL

        LDA     #PND            ; ESTABLISH LOW MEMORY LIMITS.
        STA     MEMLO
        STA     APPMHI
        LDA     #PND/256
        STA     MEMLO+1
        STA     APPMHI+1

        LDA     #RESTRT         ; ESTABLISH RESTART VECTOR.
        STA     DOSVEC
        LDA     #RESTRT/256
        STA     DOSVEC+1

        CLC                     ; SET FLAG FOR SUCCESSFUL BOOT.
        RTS

; APPLICATION INITIALIZATION ENTRY POINT.

PINIT   RTS                     ; NOTHING TO DO HERE FOR ...
                                ; ... CONTROLLING APPLICATION.

; THE MAIN BODY OF THE PROGRAM FOLLOWS.

RESTRT=*

; THE MAIN BODY OF THE PROGRAM ENDS HERE.

PND=    *                       ; 'PND' = NEXT FREE LOCATION.
        .END
```

10.3.4 Program and procedure to create cassette boot files

This section provides a procedure and a program listing that may be used to make bootable files on cassette tapes. The procedure

given is not the only one possible, and no claims are made as to its elegeance. The dialogue shown assumes that one is logged onto the PDP-11/34 computer from one of the development systems in the laboratories and is using LNBUG 2.0. A Model 400/800 with a cassette recorder is also required.

```
User: OSL <cr>

Comp: loads the operating system.

User: DLOAD BOOTCY <cr>

Comp: loads the boot file maker.

User: <CTRL-P>                    go to LNBUG control.
      X <cr>

LNBG: responds with LNBUG prompt.

User: E477G <cr>                  starts O.S. and initializes mem.

User: wait for tone indicating cassette write request.

User: <CTRL-C>                    interrupts the initialized prog.

LNBG: responds with LNBUG prompt.

User: $ <cr> <cr>                 returns to PDP-11/34 control.

Comp: .                           PDP-11 prompt.

User: DLOAD xxxxx <cr>            xxxxx = name of application file.

Comp: loads the application file.

User: <CTRL-P>                    go to LNBUG control.
      X <cr>

LNBG: responds with LNBUG prompt.

User: P                           resume 'BOOTCY'.

User: setup cassette drive to record on tape.

User: press the RETURN key on the Model 400/800 keyboard.

User: wait for completion of the cassette file write.

LNBG: responds with LNBUG prompt in response to BRK in 'BOOTCY'.

User: R                           verify BRK address.

User: to write another boot file, type B000G <cr>.
```

Shown below is a listing of the program referred to as 'BOOTCY' in the procedure above:

```
; THIS PROGRAM WRITES A SINGLE FILE TO THE CASSETTE AND IS
; USED IN CONJUNCTION WITH A PROCEDURE TO MAKE CASSETTE
```

```
; BOOTABLE FILES.  THE FOLLOWING TWO SYMBOLS MUST BE EQUATED
; USING THE MEMORY LIMITS OF THE PROGRAM TO BE COPIED:
;
;      'PST' = PROGRAM START ADDRESS (SEE SAMPLE PROGRAM).
;      'PND' = PROGRAM END ADDRESS (SEE SAMPLE PROGRAM).

PST=    $0700
PND=    $1324
FLEN=   PND-PST+127/128*128     ; ROUND UP TO MULTIPLE OF 128.

*=      $B000                   ; THIS PROGRAM'S ORIGIN.

BOOTB   LDX     #$10            ; USE IOCB #1.

; FIRST OPEN THE CASSETTE FILE FOR WRITING.

        LDA     #OPEN           ; SETUP FOR DEVICE "OPEN".
        STA     ICCOM,X

        LDA     #OPNOT          ; DIRECTION IS "OUTPUT".
        STA     ICAX1,X
        LDA     #$80            ; SELECT SHORT IRG.
        STA     ICAX2,X

        LDA     #CFILE          ; SETUP POINTER TO DEVICE NAME.
        STA     ICBAL,X
        LDA     #CFILE/256
        STA     ICBAH,X

        JSR     CIOV            ; ATTEMPT TO OPEN FILE.
        BMI     CERR            ; ERROR.

; NOW WRITE THE ENTIRE FILE AS ONE OPERATION.

        LDA     #PUTCHR         ; SETUP FOR "PUT CHARACTERS".
        STA     ICCOM,X

        LDA     #PST            ; POINT TO START OF APPLIC. PROG.
        STA     ICBAL,X
        LDA     #PST/256
        STA     ICBAH,X

        LDA     #FLEN           ; SETUP # OF BYTES TO WRITE.
        STA     ICBLL,X
        LDA     #FLEN/256
        STA     ICBLH,X

        JSR     CIOV            ; WRITE ENTIRE FILE.
        BMI     CERR            ; ERROR.

; NOW CLOSE THE FILE AFTER SUCCESSFUL WRITE.

        LDA     #CLOSE          ; SETUP FOR "CLOSE".
        STA     ICCOM,X

        JSR     CIOV            ; CLOSE THE FILE.
        BMI     CERR            ; ERROR.

        BRK                     ; STOP WHEN DONE.
```

```
CERR    BRK                     ; STOP ON ERROR.

CFILE   .BYTE  "C:",CR          ; FILE NAME.

; THIS IS THE CARTRIDGE HEADER

*=      $BFF9                   ; "A" CARTRIDGE.

INIT    RTS
        .WORD  BOOTB
        .BYTE  0,4
        .WORD  INIT

        .END
```

11. Advanced techniques and application notes

This section presents information which may be of use to the user who wishes to use the capabilities of the O.S. and use some of the hardware capabilites that aren't directly available through the O.S. and, in fact, may be in direct conflict with parts of the O.S.

11.1 Sound generation

The O.S. uses the POKEY sound generation capabilities only in the I/O subsystem, for cassette FSK tone generation and for the "noisy bus" option in SIO.

11.1.1 Capabilities

The hardware provides 4 independently programmable audio channels which are mixed and sent to the TV as part of the composite video signal. The POKEY registers shown below are all concerned with sound control (as described in the CANDY/COLLEEN HARDWARE MANUAL).

AUDCTL [D208]	Audio control.
AUDC1 [D201] & AUDF1 [D200]	Channel 1 control.
AUDC2 [D203] & AUDF2 [D202]	Channel 2 control.
AUDC3 [D205] & AUDF3 [D204]	Channel 3 control.
AUDC4 [D207] & AUDF4 [D206]	Channel 4 control.

11.1.2 Conflicts with O.S.

There are two potential conflicts with the O.S. involving sound generation:

The O.S. may generate its own sounds and then turn off all sounds as part of I/O operations to the cassette and the serial bus peripherals.

The O.S. does not turn off sounds on RESET or BREAK; if the sounds are to be turned off under those conditions, the controlling program must provide that capability.

11.2 Screen graphics

11.2.1 Hardware capabilities

The hardware capabilities for screen presentations are quite versatile; the O.S. uses a very small amount of the capability provided. The means of extension, however, are non-trivial; and making changes to a screen format while still utilizing the resident Display handler will be difficult. See the CANDY/COLLEEN HARDWARE MANUAL for information regarding screen presentations.

11.2.2 O.S. capabilities

The resident Display handler arbitrarily supports 8 of the 11 possible full screen modes (11 of 14 modes if the GTIA chip is used in place of the CTIA), and allows for an optional "split screen" text window of fixed size. The hardware allows for many more options than the Display handler supports, as will be seen

by reading the hardware manual.

11.2.3 Cursor control

The Display handler text and graphics cursors may be directly controlled by the user as described in section 5.3.2 and in section 4.5 B1-4.

11.2.4 Color control

The color register assignments that the Display handler makes upon all OPEN commands, may be altered by the user as described in section 4.5 B7-8 and elsewhere. Note that every RESET or Display handler OPEN will reset the values back to the system default.

11.3 Players/missiles

The O.S. makes no use of the player/missile generation capability of the hardware; but, luckily, it may be used independently of the O.S. with no conflict.

11.3.1 Hardware capabilities

The hardware allows a number of independently moveable screen objects (of limited width) to be positioned and moved about the screen without affecting the "playfield" (bit mapped graphics or character) data. Priority control allows the various objects to have a display precedence in case of conflict (overlap).

11.3.2 Conflicts with O.S.

The only potential problem is that the user must assure that the player/missile data is address aligned as required by PMBASE [D407]; and finding a suitable free area that is guaranteed to be free under all environments could be a problem.

11.4 O.S. timing information

11.4.1 Interrupt service timing

11.4.2 CIO function timing

11.4.3 Handler function timing

11.4.4 Floating point operation timing

11.4.5 Processor and memory timing

11.4.6 DMA (cycle steal) characteristics

11.5 Reading game controllers

The game controllers shown below are read by the O.S. as part of the stage 2 VBLANK process (see 4.5 J1-9):

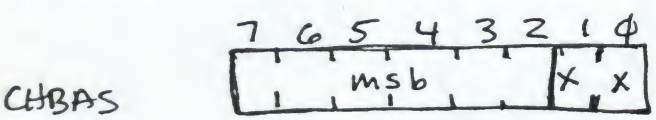
Joysticks/triggers 1-4.
Paddle controllers/triggers 1-8.
Driving controllers/triggers 1-4.
Lightpen/triger.

Insert

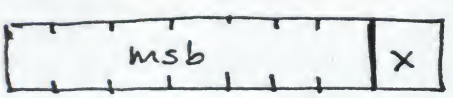
Alternate character sets

In screen text modes 1 and 2, two character sets are available, the sets being selectable by the value stored in database variable CHBAS [Ø2F4]. The default value of $EØ provides capital (upper case) letters, numbers and the punctuation characters (corresponding to display codes $2Ø through $5F in Appendix E); the alternate value of $E2 provides lower case letters and the special character graphics set (corresponding to display codes ($6Ø through $7F and $ØØ through $1F in Appendix E).

In addition, user defined character sets may be obtained for text modes Ø, 1 and 2 by provided the character matrix definitions in RAM and setting CHBAS to point to those definitions. CHBAS always contains the most significant b.its of the memory address of the start of the character definitions, as shown below:



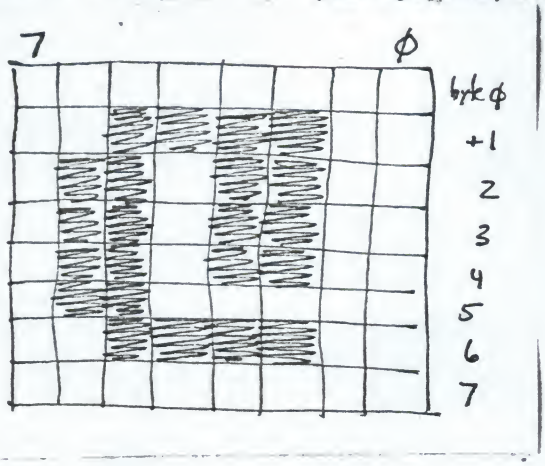
text mode Ø



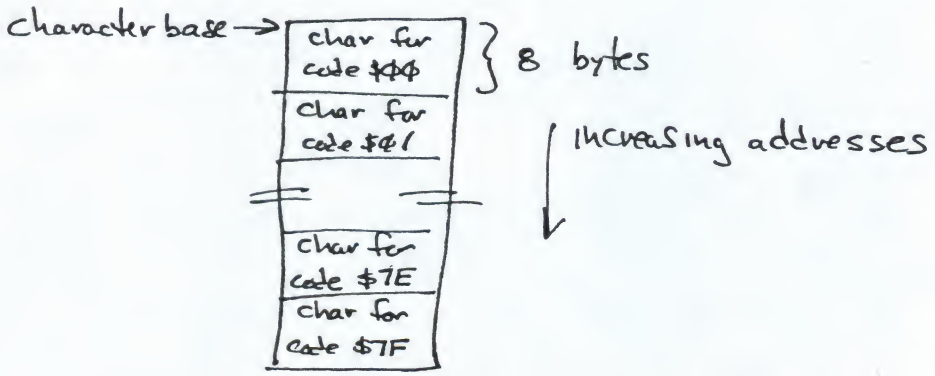
text modes 1 & 2

Where x indicates an ignored address b.t (assumed = Ø).

Each character is defined by an 8 x 8 bit matrix; the character '@' is defined as shown below:



The storage for the character set involves 8 consecutive bytes for each character with characters ordered consecutively by their internal code value (see the discussion in Appendix K relating to BSS



In addition to these controllers, other information may be sensed or sent using the PIA chip to which the console connectors are interfaced.

11.5.1 Keyboard controller sensing

The PASCAL procedure below shows how to read data from the Atari keyboard controller; the hardware register and O.S. database names used are from the O.S. equate file.

```
FUNCTION READKEY (DRIVEVAL:BYTE):BYTE;
   BEGIN
      PORTA := DRIVEVAL    { set row select };
      DELAY                { wait for O.S. to read data };
      KCODE := 0           { preset for no key read };
      IF PADDLx > 10 THEN KCODE := 1 { column 1 };
      IF PADDLx > 10 THEN KCODE := 2 { column 2 };
      IF STRIGx = 0  THEN KCODE := 3 { column 3 };
      READKEY := KCODE     { set function value }
   END;

BEGIN

   { setup PIA port A for 8 bits out }
   PACTL := $30       { direction register select };
   PORTA := $FF       { set direction bits for output };
   PACTL := $34       { data register select };

   { setup of driving values, each selects a different row }
   DVAL[0] := $EE;
   DVAL[1] := $DD;
   DVAL[2] := $BB;
   DVAL[3] := $77;

   REPEAT { loop to read the controller keys }
      I := 0;
      REPEAT
         KEY := READKEY (DVAL[I]) { read a row };
         IF KEY <> 0 THEN KEY := KEY + (I*3) { encode };
         I := I + 1                  { next row }
      UNTIL (I > 3) OR (KEY <> 0);
      IF KEY <> 0 THEN WRITELN ('KEY VALUE = ',KEY)
   UNTIL FALSE { forever! }

END.
```

11.5.2 Front panel connectors as I/O ports

The three pages that follow show how some of the pins in the front panel (game controller) connectors can be used as general I/O pins.

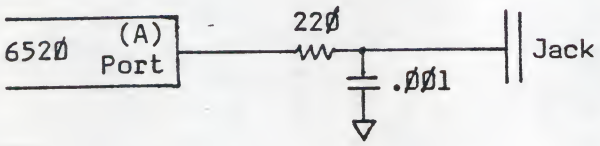
ATARI 400/800 Front Panel (Controller) Jack As I/O Ports

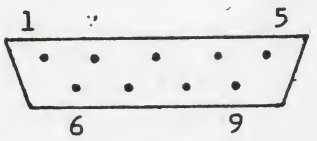
Hardware Information:

PIA (6520 / 6820)
Out: TTL levels, 1 load
In : TTL levels, 1 load

For more information refer to 6520 chip manual.

Port A Circuit (typical):





Male connector, FRONT view

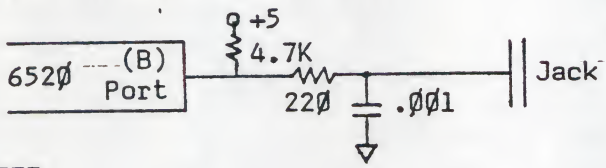
Pin 8= Ground

Pin 7= Vcc (+5v *)

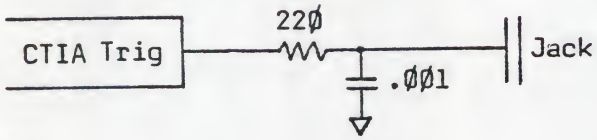
* Note: 50ma maximum total external drain on power supply allowed

---

Port B Circuit (typical):



"Trigger" Port Circuit (typical):



Software Information:

6520 PIA: (this also pertains to all of the following: **)
Port A control (address $ D302)

7	6	5	4	3	2	1	0
0	0	1	1	1	X	0	0

Write this into this register

↑ Port A Data/Data direction addressing control

0= Address data direction at $ D300

1= Address data at $ D300

** Port A data direction (address $ D300)

7	6	5	4	3	2	1	0
X	X	X	X	X	X	X	X

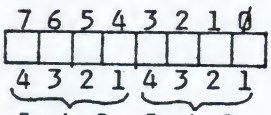
Write this into this register

↑ Data direction control for Port A

1= Out

0= In

Port A data (address $ D3ØØ)



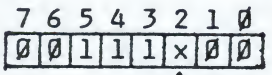
Read or Write this register

Port B control (address $ D3Ø3)

Ø	Ø	1	1	1	X	Ø	Ø

652Ø PIA:

Port B control (address $ D3Ø2)



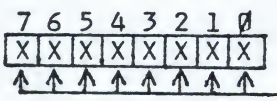
Write this into this register

Port B Data/Data direction addressing control

Ø= Address data direction

1= Address data

Port B data direction (address $ D3ØØ)



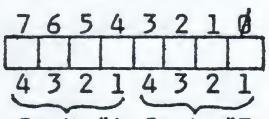
Write this into this register

Data direction control for Port B

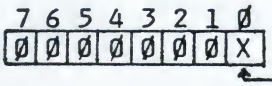
1= Out

Ø= In

Port B data (address $ D3Ø1)



Four "trigger" ports: ($ DØ1Ø, $ DØ11, $ DØ12, $ DØ13)



Read this port

Trigger value

$ DØ1Ø = Port 1 pin 6

$ DØ13 = Port 4 pin 6

Other Miscellaneous Software Information:

1). The O.S. sets up all PIA ports as <u>inputs</u> during initialization

2). The O.S. <u>usually</u> reads the above once per TV frame (during vertical blank) into RAM as follows:

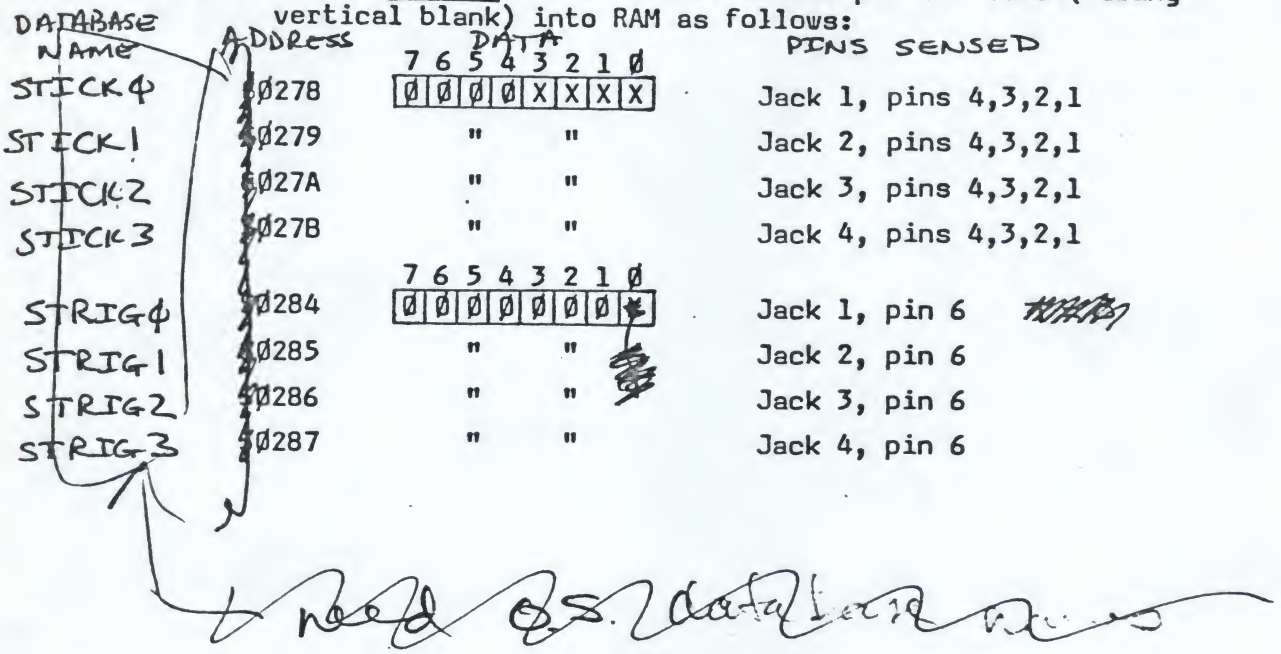
	7 6 5 4 3 2 1 Ø	
$Ø278	Ø Ø Ø Ø X X X X	Jack 1, pins 4,3,2,1
$Ø279	" "	Jack 2, pins 4,3,2,1
$Ø27A	" "	Jack 3, pins 4,3,2,1
$Ø27B	" "	Jack 4, pins 4,3,2,1

	7 6 5 4 3 2 1 Ø	
$Ø284	Ø Ø Ø Ø Ø Ø Ø X	Jack 1, pin 6
$Ø285	" "	Jack 2, pin 6
$Ø286	" "	Jack 3, pin 6
$Ø287	" "	Jack 4, pin 6

Other Miscellaneous Software Information:

1). The O.S. sets up all PIA ports as inputs during initialization

2). The O.S. usually reads the above once per TV frame (during vertical blank) into RAM as follows:



		7 6 5 4 3 2 1 0	
PADDL1	$270	X X X * X X * X *	Jack 1, pin 5
PADDL3	$272	" "	Jack 2, pin 5
PADDL5	$274	" "	Jack 3, pin 5
PADDL7	$276	" "	Jack 4, pin 5
PADDL0	$271	" "	Jack 1, pin 9
PADDL2	$273	" "	Jack 2, pin 9
PADDL4	$275	" "	Jack 3, pin 9
PADDL6	$277	" "	Jack 4, pin 9

* ~~bits~~ pins 5 & 9 are read through the paddle controller circuitry; a nominal value of 7 indicates that the pin is high (or floating) and a nominal value of 228 indicates that the pin is pulled low.

12. Atari standards

This sections states some of the program external behaviors that are considered to be important from a legal, functional or product consistency standpoint.

There are several types of programs that are to be considered and some may not have complete control of their environment, such as programs written in the BASIC language and running under the Atari BASIC interpreter.

	Cartridge	Disk	Cassette
HLL proc	R	B	B
Game (native)	R	B	B
Game (HLL)		L	L
Applic (native)	R	B	B
Applic (HLL)		L	L

Where: R indicates the software is ready to execute at power-up.
B indicates the software is bootable at power-up time.
L indicates the software is loadable by a HLL processor.

HLL stands for High-Level Language.
native stands for 6502 machine code.

12.1 Program sign-on

A copyright notice will be displayed when the system first powers up, and will include the following text:

(C) COPYRIGHT ATARI 198x

The notice should be displayed until some operator interaction with the system is observed, at which time the copyright notice may be removed. The display may be stationary, moving, blinking or non-blinking, as long as it is readable.

12.2 RESET key processing

The response to the RESET key (warmstart) should do the following:

1. Stop the on-going processes.
2. Go to the outer control level, as per power-up.
3. Set user selectable options to power-up state.
4. Don't clear the stored program (for language processors).

5. Don't clear user program variables (for language processors).

12.3 BREAK key processing

The response to the BREAK key should do the following:

1. Stop the on-going processes.

2. Go to the outer control level, as per power-up.

12.4 START/SELECT/OPTION key processing

START -- Start the currently selected process (for games).

SELECT & OPTION -- # of players (for games).
variations (for games).

12.5 DOS/blackboard entry

Language processors should contain operator directives to allow the user to go to a booted utility (e.g. DOS) or to the blankboard mode; typically two commands would be provided: DOS and BYE. The minimal action for these commands is shown below:

DOS -- Go to booted utility

```
JMP     (DOSVEC)      where DOSVEC = 000A.
```

BYE -- Go to blankboard mode

```
JMP     BYELOC        where BYELOC = E471.
```

In addition, it is imperative that IOCB 0 be assigned to the Screen Editor with the following display options set as per power-up:

```
Cursor not inhibited      CRSINH [02F0] = 0
Display flag reset        DSPFLG [02FE] = 0
Invert flag reset         INVFLG [02B6] = 0
```

12.6 Program pause (display freeze/unfreeze)

CTRL-1 or space bar should be able to freeze the action (pause the on-going process) in a non-destructive manner; pressing the key a second time should resume the process.

12.7 Operator prompting

When using the Screen Editor for operator I/O, text prompts

should contain at least one EOL.

12.8 Controller assignment

Controllers are assigned from left to right.

12.9 In-house standards documents

The pages following contain copies of two Atari in-house standards documents issued in 1980. Any information in those documents that conflicts with information presented in the prior paragraphs should be given precedence.

Dennis Koble
6/04/80

ASSEMBLY LANGUAGE GAME CARTRIDGES

Absolute Guidelines:

1. Game Start key starts game initially and restarts game with current options intact if pressed during game play.

2. System Reset-enters warm start of cartridges and thus causes complete reset of game and all options.

3. Game select and Game Option: Should cause a clearly visible indication on the screen that a different game or option has been entered. The game option switch should select number of players in a multi-player game while the game select should select the game variations. If held down, the game selection or option should increment approximately every .5 second.

4. If a light pen is used in the game it must be available as an option to be used as an alternative to a joystick or paddle controller, unless the game clearly depends on only a light pen.

5. Cartridge copy protection must be included in the code. This may involve storing break instructions into critical ROM locations, checking for program operation within a valid cartridge address range, verifying program code is stored in ROM (not Ram) and other means determined to prevent unauthorized cartridge duplication into RAM or on diskette.

6. The game name should appear on the screen (should be large and easy to read). Also on the Screen, preferably center bottom should be the following info.

   "Copyright" can also be spelled out. If the circle C or circle R cannot be used (if you choose to use the O.S. character set for instance) then (C) and (R) may be used with copyright spelled out although they are not as strong legally.

7. Game controllers, if used, should be assigned from left to right.

Possible Guidelines:

1. Control 1 may make game pause during game play. Pressing it again would cause the game to continue. If the keyboard is not used in the game play, any key may be used to pause the game.
2. Game Select and option switches may have some defined effect during game.
3. On menu driven programs, the break key may cause termination of currently executing phase and return control to an outer loop.
4. Allow the user to use either the joystick or cursor controls interchangeably if the game is a non real-time game.

BASIC GAMES - CASSETTE

Absolute Guidelines:

1. Game Start key will restart game at any time during game play.

2. Program should poke out any key input retained in buffer before it requests a new key input. This prevents inadvertent entries.

3. Program should ignore lower case and Atari inverted modes and accept any keys in those modes as upper case except as where those modes are essential to the game.

4. Instructions must load in the same size memory as specified for the main program. For example a 16K program should have instructions that also fit in 16K.

5. Program names that are to be trademarked should be so indicated by a lower case tm following the program name on the screen.

6. Games using Joystick should also interchangeably accept curser control arrows and carriage return as similiar imput.

7. Controllers, if used, should be assigned from left to right.

8. To save space in a tight program, POKEs should be used instead of SETCOLOR commands to save a few bytes.

Format

BASIC GAMES - CASSETTE

Side A
1. Program to display program name, Atari Logo, copyright, and assembly program to do CRUN.

2. Instructions on screen overlayed with verbal instructions and background music, includes assembly program to do CRUN.

3. Program overlayed with music.
User types CLOAD, carriage return followed by any key to load tape. After loading, program then asks user whether he wants instructions on screen. User types either yes or no followed by a carriage return (optional). After loading, program then begins automatically.

Side B
1. Same as side 1 step 1.

2. Same as side 1 step 3.

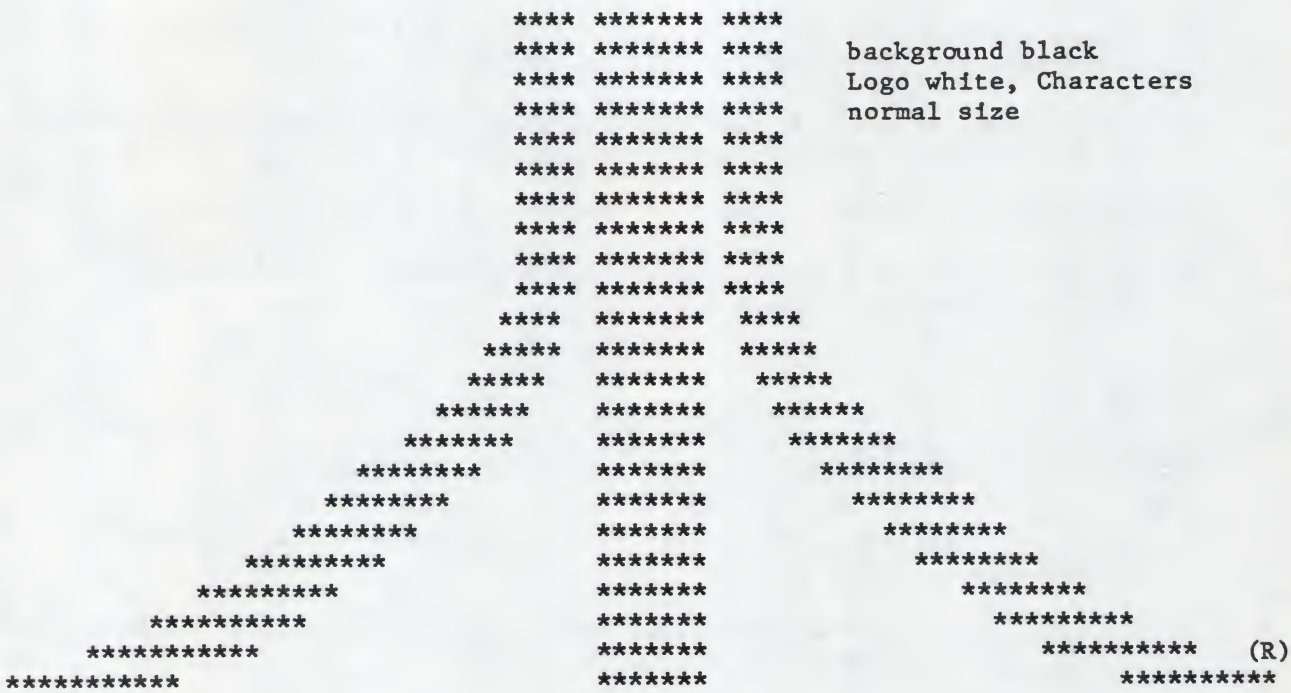
ASSEMBLER GAMES - CASSETTE

1. Standard default is where game loads and executes immediately.
User depresses start button when computer turned on, causes tape to boot.

LOGO

LOADING
(Program Name)

background dark blue
characters light blue
double wide double high



background black
Logo white, Characters
normal size

(R)

---

background dark blue

ATARI PCS
APPLICATIONS SOFTWARE STANDARDS

REV 1.0, 7/01/80

-BY-
DALE YOCUM

PREFACE

One the most important factors in any application program is usability. If the customer can't figure out how to use your latest creation then, no matter how many jazzy features it might have, he won't bother with it. He will also be less inclined to buy other Atari programs. While it may take longer to develop high quality software, in the long run we will be far more successful in the marketplace. The quality of our product is our most important asset. It must never be compromised.

GENERAL CONCEPTS

1) It should be obvious to the user at every step in the program what is expected of him.

THINGS TO USE
A) Menus (for three or more choices)
B) YES/NO questions
C) Single word answers to questions where the number of choices is three or less.
D) HELP commands
E) Short instruction frames
F) Cursor controls
G) OPTION, SELECT & START keys, when called out on the screen as being active.

THINGS TO AVOID
A) Undescribed choices/options
B) CNTRL shift user inputs
C) Single letter commands when no menu is provided.
C) Computer jargon. When possible, all instructions, questions and responses should be in normal English.
D) Heavy reliance on a separate manual for normal operation.

2) There should be no way for the user to receive a system error message while running an application program. The program should trap these out and handle them internally. Hardware errors are the exception to this rule.

3) Feedback should be given the user that his program is running. There should never be a delay of more than three seconds between a user action and a response by the computer.

THINGS TO USE
A) Echo characters inputted.
B) "Please Standby" type messages
C) Countdowns to completion of task.
D) Flashing displays
E) Estimated computation time displays
F) Audio cues (careful here as some users will not have the sound turned up).

THINGS TO AVOID
A) Hiding in a hole for more than three seconds
B) Allowing a user to get nervous. The longer the wait, the better the feedback required in the program.

4) The man-machine interface should be as natural as possible. This is the hardest area to pin down as a standard. Every effort should be made

by the software staff to design software which is easy (do I dare say fun?) to use.

THINGS TO TRY

A) Joy Sticks
B) Pot Controllers
C) Light Pens (as an option only, they're too expensive to use on a whim)
D) Rotating fields, changed by cursor position or option keys.
E) Use of screen editor to alter data.
F) Use of meaningful mnemonics and keywords for commands.
G) Graphical presentations of information are always more desirable than strictly numerical ones.
H) Color coded fields, messages and screens.
I) Flashing cursor (when it may be hard to find on the screen).

SPECIFIC GUIDELINES

1) The first screen of all applications programs should display both the name of the program and the copyright notice. If you are using the standard character set then the copyright message should appear as:

COPYRIGHT (c) 1980, ATARI

If you are defining your own character set, then a © character may be used instead of the word 'COPYRIGHT'.

2) All programs should have a revision number associated with them. This number should always appear in the first comment line of the program itself. In many applications, it is also desirable to have the revision number appear on the screen along with the program name and copyright notice.

Preliminary (not yet released) programs should start with the revision 0.0. Changes to these preliminary programs should increment the digit to the right of the decimal point -

0.1, 0.2, ... 0.9, 0.10, 0.11, 0.12 ... 0.99

Upon release of the program the revision number should be changed to 1.0. Minor changes are then indicated by incrementing the digit to the right of the decimal. Major changes are shown by incrementing the digit to the left of the decimal. A minor change is defined as any change which does not alter the functional capabilities of the software. For example, a minor change would be a bug fix - a major change would envolve adding more menu options.

3) Light pens, if used, should be an optional accessory. The program should accept inputs from another source (joysticks, cursor controls, etc.) as well. The exception to this are programs which would be impossible without this accessory (a drafting program, for example).

4) Controllers (pot controllers, joysticks, etc.) should be assigned from left to right.

5) Unless there is some unusual reason not to, all programs should POKE out any key retained in the type-ahead buffer before requesting a new input. This helps prevent inadvertent entries.

6) When practical, programs should ignore or reset lower case and Atari invert modes on user responses. Many inexperienced users will get into

these modes by accident and may be unaware of it.

7) All programs should make use of various colors for different levels of the program. The use of color can be helpful to the user as an additional cue as to what is going on (Red for an error screen, etc.). Color also adds interest and sex appeal to the software. These screen colors must meet three criteria:

A) Colors used must show up on black and white televisions.
B) The use of color must not be essential to the operation of the program.
C) The colors should be chosen so as to minimize artifacting on color televisions.
D) Color usage should be consistent throughout the program.
E) See appendix A for a list of possible colors.

8) Audio cues are also important to the usability of a program. Sounds should be chosen to have a certain meaning thoughout a program- "INPUT ERROR", for example. Sound is also useful as a "Hey, look at the screen" signal. It should be used whenever an unexpected message is being displayed or after a long computational delay.
Note: See appendix B for a list of possible sounds.

9) Menus should generally be used when ever a user is to decide between more than two items. Menus should be keyword driven rather than letter or number driven. The user responds by typing as much of the keyword as is necessary to distinguish it from the other options. Normally the input will be terminated by a RETURN (see #10 below).
If program space is available, a tree structure should be used for menu systems which are deeper than one level. At any point, the user should be able to return to the current menu level or be able to go to the next higher level.

10) In most cases, inputs from the user should be terminated by a RETURN. If you decide not to use a RETURN as a terminator - instead using a single key stroke which is self terminating- the structure of the program must meet the following criteria:

A) If the user hits a RETURN anyway, it should be ignored, and cause no ill side effects.
B) It must be simple to get back to the upper level if the user makes a mistake on input. There should be no time delay in this procedure.
C) The choices at the input in question must be such that no 'fail safe' RETURN is needed. (One of the options should not be 'Compute PI to 10000 places', for example). A nice thing about using RETURN as a terminator is that it gives the user a chance to correct an input mistake. One must be more careful of the consequences of an erroneous input, otherwise.

PROGRAM DOCUMENTATION

One of hazards of writing software is the ever present threat of having to understand what you wrote - a year later. Even worse is the thought of trying to understand someone ELSE'S code. Documentation won't make the experience a pleasant one, but at least you'll be able to sleep at night.

When a project is completed, it is the programmers responsibility to create a documentation packet for the program. At a minimum, this packet contains the following information:

A) Fully commented program listing. The comments can be supplemented with a marked up listing if appropriate.
B) With BASIC programs, a listing of the compacted version should also be included.
C) A system-level block diagram or description.
D) A description of the data structures used in the program. This should include diagrams of disk/cassette file formats, pointer arrays, data arrays, etc.
E) A list of variables used in the program and their function.
F) A cross reference listing of the program, if available.
G) Any helpful hints, random notes, descriptions of unusual PEEKS or POKES, etc. Anything that might help someone understand and modify the program.

With all documentation, assume the reader is someone with reasonable technical knowledge of the 800, but who has had no exposure to your particular program.

You should make an effort to make your source code as readable as possible. In BASIC, for example, you should generally avoid having multiple statements on a line. You should also include comments on specific lines which contain especially tricky logic.

SOFTWARE DEVELOPMENT SEQUENCE

Following is a step by step description of how an application program is developed. Under each step is a list of the responsibilities of the software engineer. In some cases, one or more steps may not apply:

1) INITIAL RESEARCH, IDEA DEVELOPMENT.
   A) Survey marketplace for similar software, acquire packages which look especially competitive.
   B) Research the area- buy or borrow books on the subject, if necessary.
   C) Write a one page preliminary concept paper to be given to marketing.
   D) Estimate rough schedule for project.

2) MARKETING IDEA REVIEW
   A) May be asked to present idea verbally at Marketing/Software meeting.
   B) IF idea approved GOTO 3

3) PROGRAM SPECIFICATION
   A) Continue research in area.
   B) Continue to acquire books and programs in area of interest, if necessary.
   C) If necessary, write programs to test concepts.
   D) Develop detailed block diagram of overall project.
   E) Create final project schedule
   F) Write detailed final specification.

4) TECHNICAL SPECIFICATION REVIEW
   A) Participate in a technical design review of program by other members of software staff.
   B) Make appropriate changes to specification, if any. Go back to step 3 if necessary.

5) MARKETING SPECIFICATION REVIEW
   A) Send final written specification to marketing.
   B) May be asked to make a verbal presentation and answer questions at Software/Marketing meeting.
   C) Make appropriate changes to specifications, if any. Go back to step 3 if necessary.
   D) IF final go-ahead THEN GOTO 6

6) PROGRAM DEVELOPMENT
   A) Proceed with actual coding of program(s).
   B) Develop documentation
   C) Conduct preliminary demonstrations with Management/Marketing.
   D) Conduct one-on-one in-progress reviews with Marketing's technical representative.

7) SOFTWARE DESIGN REVIEW
   A) Participate in a technical design review of the completed software. The review will focus on the human interface side of the finished program. The review will be attended by interested members of the software staff.
   B) Make appropriate changes to software, if any.

8) ENGINEERING CHECKOUT
   A) Create rough operator's manual, usable by both the Engineering evaluation group and by Marketing.
   B) Support the evaluation group in their checkout of your software.
   C) Correct any bugs discovered.

9) MARKETING REVIEW
   A) Support Marketing review staff in the review of your program.
   B) Respond to Marketing input on program, making those changes that are both possible and warranted.
   C) Formulate written response to Marketing describing what changes were made and reasons why others were not.
   D) If any changes were made, GOTO 8

10) DOCUMENTATION
   A) Create complete documentation package for program as described previously.
   B) Support technical writing staff on creation of user's manual.

APPENDIX A,B

These lists of possible colors and sounds will be provided at a future date.

13. Program development

This section provides information to aid a programmer working at the Atari facility (or at a facility with similar development equipment) in the mechanics of entering, assembling and testing assembly language programs written for the Atari 400/800 computer.

The basic scenario for program development includes the steps shown below:

Program entry to host system using a text editor.
Assembly of program using host system cross assembler.
Correction and revision of program using text editor.

Download program object code to a development system.
Debug and test program on development system.
Return to host system for permanent changes to program.

Prepare program production diskettes on host system.
Test program in a production system, using EPROMs.

Release mask ROM data for production.
Program source and object files go to archival storage.

Section 13.1 discusses the use of one of the non-6502 "host" computers for program preparation and maintenance, while section 13.2 discusses the debug and test activities to be performed at the 6502 development system stations.

13.1 How to use the host computer for program development

Most assembly language program editing and assembling will be done on computers other than the Atari 400/800; although the Atari computer has an Assembler/Debugger/Editor cartridge, the speed, peripheral complement and ease of use of the other host computers make them more desirable for large program development. There are three different host system configurations available for the development of 6502 assembly language programs: 1) a PDP-11/34 running the TSX-11 operating system, 2) several Andromeda LSI-11s running with RT-11, and 3) a Tandem computer.

13.1.1 PDP-11/34 (TSX-11)

There is a single PDP-11/34 for consumer software development at Atari. There are terminals in many of the offices and laboratories which connect to this computer.

HARDWARE

The PDP-11/34 has the following configuration:

ADM-3A terminals (multi-user O.S.)
Printronix printer
1 RK05 cartridge disk drive (2.5 Mbytes)
1 RK05 fixed disk drive (5.0 Mbytes)
2 RX01 floppy disk drives (250 Kbytes each)

The following rules govern the use of the disks:

DK0 (fixed disk) is for system use only (no user programs).
DK1 (fixed disk) is for user source files.
DK2 (removable) is for user object files and scratch files.
DX0 and DX1 diskettes are supplied by the user.

All DK file names must end with the user's assigned code letter, because there is only one directory for each disk.

The DK disks are backed up on a regular schedule as shown below:

DK1 (user disk) daily backup -- there is a set of disks (one for each working day) which contains the backup of DK1 for the prior 5 working days.

DK1 (user disk) weekly backup -- there is a another set of disks which contains the Friday (Monday morning) backups of DK1 for each Friday of the prior 4 weeks and one backup for each month for the prior 5/6 months.

DK0 (system disk) weekly backup -- there is a set of 4 disks which contains the Friday backups of DK0 for each Friday of the prior 4 weeks.

DK2 (scratch disk) is never backed up.

Inactive files which are to be archived may be stored on floppy diskettes or transferred to the Archive (cartridge) disk by request.

OPERATING SYSTEM

The operating system used is TSX-11, which is basically a multi-user version of RT-11.

The capabilites most used:

MONITOR COMMANDS -- DIR,COPY,DELETE,RENAME,etc.
TEXT EDITOR
CROSS ASSEMBLER
PIP -- DEVICE/FILE MANAGEMENT

ASSEMBLER

The cross assembler used was obtained from Boston Systems Office, Inc.

To assemble a program, one of two forms for invoking the cross assembler may be used, as shown below:

```
.RUN CA6500<cr>

6500 CROSS ASSEMBLER VERSION x.x
COPYRIGHT, THE BOSTON SYSTEMS OFFICE, INC. 1977
(617) 890-0888
*[<object file>][,<list file>]=<source file><cr>
```

or

.RUN CA6500<sp><source file><sp>[<object file>][,<list file>]

In addition to these forms, several command files have been provided to aid in assembling programs which utilize the O.S. equate file (DK1:NEQATL.SRC).

ASEMBL <filename><cr> -- will assemble the file DK1:<filename>.SRC plus the equate file, produce a line printer listing of the entire assembly, and produce an object file DK2:<filename>.OBJ.

NOEQFL <filename><cr> -- is the same as ASEMBL except that the listing does not contain the O.S. equate file.

NOLSTL <filename><cr> -- is the same as ASEMBL except that no listing is produced.

DOCUMENTATION

The following documentation relating to the use of the PDP-11/34 host computer is available at the Atari facility.

RT-11 POCKET GUIDE
RT-11 Documentation Set (volumes 1-6)

The RT-11 Documentation Directory is contained in volume 1 of the RT-11 Documentaion Set, and describes the contents of the six volumes.

13.1.2 Andromeda (RT-11)

HARDWARE

Each of the Andromedas has the following configuration:

1 ADM-3A terminal.
Printer
2 RX01 floppy disk drives (250 Kbytes each)

The following rules govern the use of the disks:

DX0 is for system use only (no user programs)
DX1 is for user files, user provides own medium.

Because the user provides his own diskettes, there are no rules or restrictions regarding disk usage.

Each printer is connected to a switch box which allows the printer to be connected to one of two possible Andromeda systems. The switch must be in the proper position in order for an Andromeda to communicate to a printer.

OPERATING SYSTEM

The operating system used is RT-11.

The capabilites most used:

MONITOR COMMANDS -- DIR,COPY,DELETE,RENAME,etc.
TEXT EDITOR

CROSS ASSEMBLER
PIP -- DEVICE/FILE MANAGEMENT

ASSEMBLER

The cross assembler used was obtained from Boston Systems Office, Inc. and is the same one as used on the PDP-11/34.

DOCUMENTATION

The following documentation relating to the use of the Andromeda host computer is available at the Atari facility.

RT-11 POCKET GUIDE
RT-11 Documentation Set (volumes 1-6)

The RT-11 Documentation Directory is contained in volume 1 of the RT-11 Documentaion Set, and describes the contents of the six volumes.

13.1.3 Tandem

HARDWARE

No information available at the time of this writing.

OPERATING SYSTEM

No information available at the time of this writing.

ASSEMBLER

The cross assebler used was obtained from Microtec.

DOCUMENTATION

No information available at the time of this writing.

13.2 Program debug environment

In order to test a program, the program object code is downloaded from the host to a development system via a communication link between the two systems. The development systems for the Atari 400/800 are single user stations which have the following features:

Full hardware emulation of an Atari 800 computer.
Atari keyboard.
Color Television monitor.
Optional Atari peripherals such as disks, printers, etc.
Optional Atari controllers such as joysticks, etc.
RAM in the cartridge ROM address space.
Resident debug monitor (LNBUG).
H-P Logic Analyzer monitoring the 6502 address bus.
Communications link to the PDP-11/34.

13.2.1 LNBUG

LNBUG is an interactive 6502 program debugger which has many commands, most of which relate to the general functions shown below:

Examination and alteration of memory in several formats.
6502 code mini-assembler and disassembler.
6502 trace/single-step/breakpoint/register manipulation.
Host computer communications link management.

There are user manuals available for the various versions of LNBUG in use at Atari; these manuals provide complete operating information for LNBUG.

Whenever the development system is hardware RESET, it comes up under control of the LNBUG monitor, which is always resident. The user then downloads his program, patches the program, sets program breakpoints, monitors program execution, examines program memory, etc. using the ADM-3A CRT terminal for comunication to LNBUG. There are several versions of LNBUG in use, each with differing command syntax, so the user will want to consult the appropriate LNBUG manual for specifics.

Note that using LNBUG for program breakpoints and tracing alters the timing of the program being executed; to monitor in real-time, the H-P Logic Analyzer must be used.

13.2.2 Development system restrictions

The development system imposes some restrictions upon the user, primarily because of LNBUG requirements; these restrictions are itemized in the remainder of this subsection.

1. The development system version of the O.S., which is downloaded from the host computer, is different from the ROM version found in the end product. The development system version requires some extra code to interface with LNBUG and uses RAM from 9000 to 9020 to contain that code which sets the hardware interrupt vectors at FFF8 and FFFA (overrides LNBUG's assignment of those vectors); this conflicts with the dedication of 8000-9FFF as the cartridge B address space.

2. LNBUG uses RAM locations 0000 and 0001.

3. NMI may be disabled by some versions of LNBUG.

4. LNBUG uses RAM in the 8000 to 87FF region in some versions of LNBUG; this conflicts with the dedication of 8000-9FFF as the cartridge B address space.

5. The development system has no RAM at 8800-8FFF for some versions of LNBUG; this conflicts with the dedication of 8000-9FFF as the cartridge B address space.

6. LNBUG resides at 6000 to 7FFF.

7. Addresses 5000 to 5FFF contain no memory, which limits the maximum RAM memory configuration that can be tested to 20K bytes.

8. If interrupts are to occur while LNBUG 5.0 is running, no interrupt routine should use zero page locations FC-FF as this will crash LNBUG.

13.2.3 Loading the program and operating system

In order to test a program on the development system, it is necessary to simulate the environment of a standalone Atari 400/800. The necessary hardware emulation is provided by the development system; however, none of the operating system firmware is resident. Where the Atari computer has the O.S. ROMs, the development system has RAM into which the O.S. can be downloaded from the host computer. The development system also has RAM in the cartridge address spaces for downloading.

13.2.3.1 Downloading from the PDP-11/34

ESTABLISHING COMMUNICATION WITH HOST

The first thing that must be accomplished is to establish communication with the PDP-11/34 from the development system CRT terminal. This is done by entering $<cr> to the LNBUG monitor. The minimum response from the PDP-11 will be a period ('.') prompt, although more text will be received when the terminal first logs on.

LOADING THE ATARI 400/800 OPERATING SYSTEM

After having established communication with the PDP-11/34, the Atari computer operating system, sans the floating point package, may be loaded to the development system by entering:

    OSL<cr>

The operating system code will now download to the development system, displaying to the CRT terminal as it is received; lengthy delays are normal during this process due to other user activity on the PDP-11.

LOADING THE ATARI 400/800 FLOATING POINT PACKAGE

After having established communication with the PDP-11/34, the

Atari computer floating point package may be loaded to the development system, if needed, by entering:

    DLOAD D800L<cr>

The floating point package will now download to the development system, displaying to the CRT terminal as it is received; lengthy delays are normal during this process due to other user activity on the PDP-11.

LOADING THE APPLICATION PROGRAM

After having established communication with the PDP-11/34, the user application program may be loaded to the development system by entering:

    DLOAD <filename><cr>

where <filename> is the name of an .OBJ file on DK2; note that neither DK2: nor .OBJ are specified as part of the DLOAD syntax. The application program will now download to the development system, displaying to the CRT terminal as it is received; lengthy delays are normal during this process due to other user activity on the PDP-11.

13.2.3.2 Downloading from the Andromeda

The Andromeda systems do not have a data link to the development systems, but the diskettes used on the Andromeda system are compatible with the PDP-11/34; so, the object files can be transferred to DK2 of the PDP-11/34, and the download process would then proceed as described in the prior paragraph.

13.2.3.3 Downloading from the Tandem

No information available at the time of this writing.

13.2.4 H-P Logic Analyzer

The development systems have Hewlett-Packard Model 1611A Logic State Analyzers with Option A65 Personality Modules for the 6502 Microcomputer. The Model 1611A is a passive test instrument which allows the user to monitor the activity of the external bus of the 6502, in real-time.

There are two manuals available which describe the analyzer:

    OPERATING AND SERVICE MANUAL
    1611A LOGIC STATE ANALYZER

    OPERATING AND SERVICE MANUAL SUPPLEMENT
    1611A OPT A65 (10261A)
    PERSONALITY MODULE FOR 6502 MICROPROCESSORS

The Option A65 supplement contains all of the information required for the normal usage of the device; the other manual contains installation and service information.

13.3 In-system testing

After a program has been debugged and tested in the development system environment, it should then be tested in a standard Atari computer; this requires that the program be stored in some form of Read Only Memory, currently 16K bit or 32K bit EPROMs, which are installed on a cartridge Printed Circuit Board (PCB).

At this point, the program can be distributed to marketing, test sites, other programmers, etc. for further testing before the mask ROM production data is sent out to a ROM vendor.

13.3.1 Differences between development & production systems

The primary functional differences between the development hardware/O.S. and the production hardware/O.S. are based upon the restrictions listed in section 13.2.2. The major differences are summarized below:

Not all of the cartridge B address space is available in the development system.

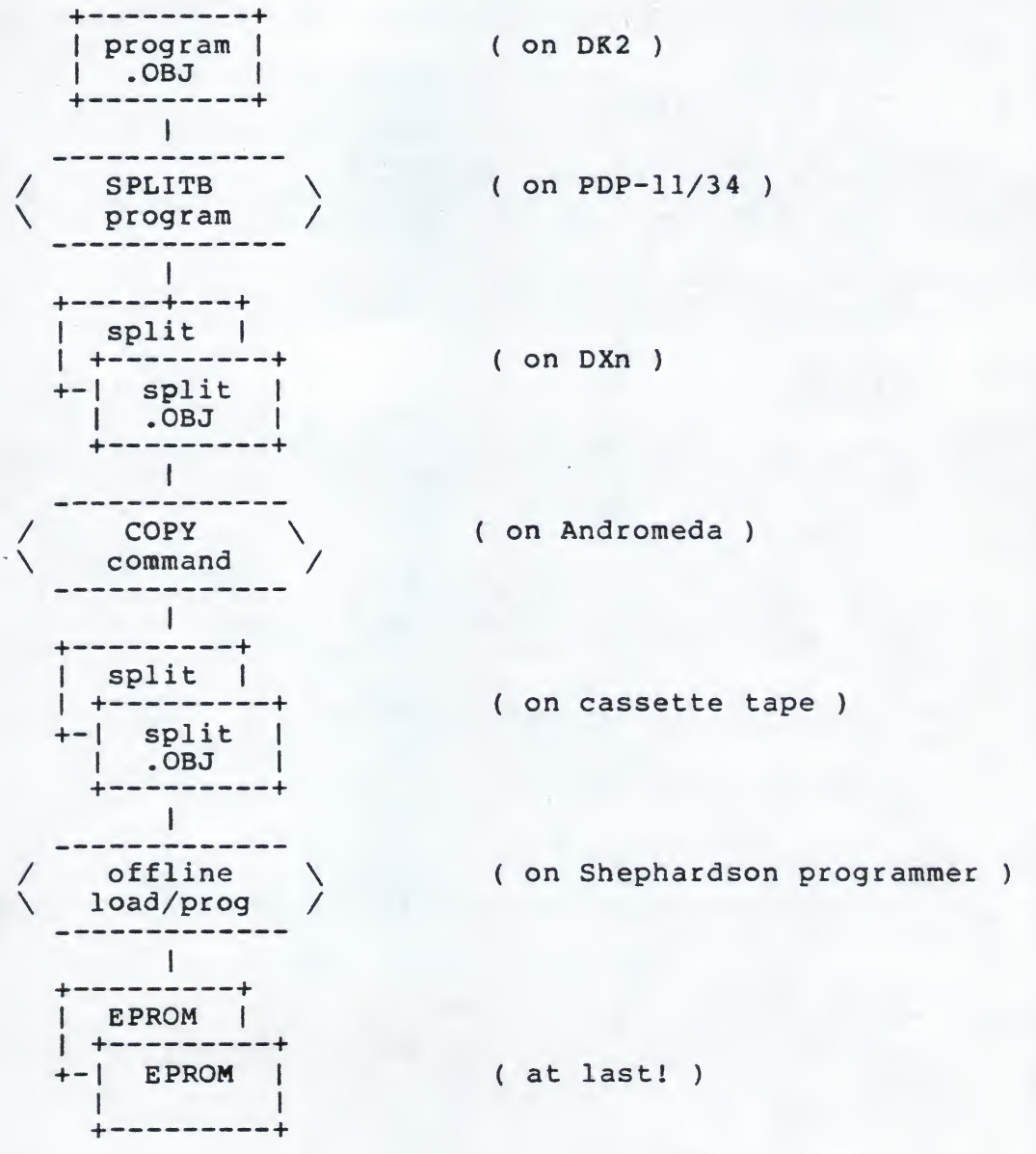
The RAM configuration is fixed at 20K bytes, instead of being variable from 8K bytes up to 48K bytes.

13.3.2 Preparing EPROMS

Neither the host systems nor the development systems currently have the ability to directly program the EPROMS that are required for final test. The EPROM programming activity is performed off-line, using a cassette tape for data transfer.

13.3.2.1 PDP-11/34

The procedure for getting the program object code to the EPROM programmer from the PDP-11/34 is shown below:



1. Split the program object file into separate object files (on 4K address boundaries) using the SPLITB utility on the host. The split object files go directly to a diskette.

2. Copy each split object file to the beginning of a cassette tape, using both sides of a tape to hold one file on each side.

The TI Silent 700 coupled to an Andromeda is used for this operation.

3. Read each split object file into the EPROM programmer and program the EPROM(s).

PROGRAM SPLITTING

An example of the use of the splitter utility is shown below; user responses are underlined:

```
.RUN BASIC<cr>
OPTIONAL FUNCTIONS (ALL, NONE, or INDIVIDUAL)? <cr>

READY
RUN DK1:SPLITB<cr>
OBJECT FILE SPLITTING PROGRAM (4K CHUNKS)
INPUT FILE? DK2:XGAMEY.OBJ<cr>
OUTPUT FILE #1? DX1:XGAM1Y.OBJ<cr>
OUTPUT FILE #2? DX1:XGAM2Y.OBJ<cr>

 343 RECORDS PROCESSED
 1   SPLITS ENCOUNTERED

READY
BYE<cr>
```

See the next subsection for a discussion of the copying of the diskette files to cassette tape.

13.3.2.2 Andromeda

The steps for the Andromeda computer are essentially the same as for the PDP-11/34, except DX1 would substitue for DK1 in the splitting example, as the source of the splitter program.

The remainder of this subsection applies to both the PDP-11/34 and the Andromeda systems.

DISKETTE TO CASSETTE COPY

The diskette file to cassette copy procedure requires an Andromeda system, a "Kim box", and a TI Silent 700 terminal. The following switch settings should be established before the file copy starts:

KIM BOX

Rotary switch on front panel to position 'C' (full CW).

TI 700

SPEED (HIGH/LOW) = HIGH.
RECORD (LINE/OFF/LOCAL) = LINE.
PRINTER (LINE/OFF/LOCAL) = OFF or LOCAL.
PLAYBACK/RECORD select = RECORD for drive being used.
TAPE FORMAT (CONT/LINE) = LINE.

Place cassette tape in drive being used.
Press REWIND and wait for tape to stop and END indicator

to light.
Press LOAD/FF and wait for tape to stop and READY indicator to light.
Press RECORD CONTROL (ON/OFF) to ON; indicator should light.

At the Andromeda type: COPY DX1:<filename> KB:<cr>

When the copy file operation is completed, a '.' prompt will display at the CRT terminal; now do the following to terminate the file just written to the cassette tape.

TI 700

KEYBOARD (LINE/OFF/LOCAL) = LOCAL.
RECORD (LINE/OFF/LOCAL) = LOCAL.

Press RECORD CONTROL (ON/OFF) to ON; indicator should light.
Press CONTROL-S on the keyboard several times.
Press RETURN on the keyboard several times.

CASSETTE TO EPROM TRANSFER

The cassette tape is taken to the EPROM programmer (which has an attached TI 700). The following switch settings are established before loading the program object code to the EPROM programmer.

TI 700

SPEED (HIGH/LOW) = LOW or ON LINE/OFF LINE = ON LINE.
KEYBOARD (LINE/OFF/LOCAL) = LINE.
PLAYBACK (LINE/OFF/LOCAL) = LINE.
PRINTER (LINE/OFF/LOCAL) = LINE.
PLAYBACK/RECORD select = PLAYBACK for drive being used.

Place cassette tape in drive being used.
Press REWIND and wait for tape to stop and END indicator to light.
Press LOAD/FF and wait for tape to stop and READY indicator to light.
Type: S0,0-FFF<cr> to clear the internal memory of the programmer.
Type: L5,<addr><cr> where <addr> is the target address for the code segment to be loaded; for example:
L5,A000<cr> for the 1st 4K of an 8K cartridge.
L5,B000<cr> for the 2nd 4K of an 8K cartridge.
Press CONT START/STOP to CONT START; indicator should light.

EPROM PROGRAMMER

Set the EPROM selector to the appropriate device type about to be programmed (normally 2532).
Put one or more erased EPROMs in the sockets, with the notch in the EPROM case facing toward the back of the programmer unit.
Validate that the EPROMs are erased by pressing the ERASE button; the pass indicator will light for all EPROMs that are properly erased.

Press the PROGRAM button and wait for the checksum to print on the TI 700, indicating the completion of the operation..
Check the pass/fail indicators for each EPROM.
The EPROMS may be double checked by pressing the VERIFY button; the pass/fail indicators will show the status of each EPROM.

Repeat the entire operation above as many times as necessary, loading a different 4K segment of the program each time.

Note: to abort any on-going operation, press the RESET button on the programmer.

13.3.2.3 Tandem

No informatation available at the time of this writing.

13.3.3 Configuration testing

Part of the normal testing of a program should include configuration testing; that is, testing the program with the minimum and maximum RAM memory supported, with various of the peripheral devices to be supported, and in various combinations.

LIST OF APPENDICES

Appendix A -- CIO COMMAND BYTE values.

Appendix B -- CIO STATUS BYTE values.

Appendix C -- SIO STATUS BYTE values.

Appendix D -- ATASCII codes.

Appendix E -- Display codes (ATASCII).

Appendix F -- Keyboard codes (ATASCII).

Appendix G -- Printer codes (ATASCII).

Appendix H -- Screen mode characteristics.

Appendix I -- Serial Bus I.D. and command summary

Appendix J -- ROM vectors

Appendix A -- CIO COMMAND BYTE values

The following hex values are known to be legitimate CIO commands.

Most handlers:

- 03 -- OPEN
- 05 -- GET RECORD
- 07 -- GET CHARACTERS
- 09 -- PUT RECORD
- 0B -- PUT CHARACTERS
- 0C -- CLOSE
- 0D -- GET STATUS

Display handler only:

- 11 -- FILL
- 12 -- DRAW

Disk File Manager only:

- 20 -- RENAME
- 21 -- DELETE
- 22 -- FORMAT
- 23 -- LOCK
- 24 -- UNLOCK
- 25 -- POINT
- 26 -- NOTE

Appendix B -- CIO STATUS BYTE values.

Shown below are the known CIO STATUS BYTE values.

01 (001) -- OPERATION COMPLETE (NO ERRORS)

80 (128) -- BREAK KEY ABORT
81 (129) -- IOCB ALREADY IN USE (OPEN)
82 (130) -- NON-EXISTENT DEVICE
83 (131) -- OPENED FOR WRITE ONLY
84 (132) -- INVALID COMMAND
85 (133) -- DEVICE OR FILE NOT OPEN
86 (134) -- INVALID IOCB NUMBER (Y reg only)
87 (135) -- OPENED FOR READ ONLY
88 (136) -- END OF FILE
89 (137) -- TRUNCATED RECORD
8A (138) -- DEVICE TIMEOUT (DOESN'T RESPOND)
8B (139) -- DEVICE NAK
8C (140) -- SERIAL BUS INPUT FRAMING ERROR
8D (141) -- CURSOR OUT OF RANGE
8E (142) -- SERIAL BUS DATA FRAME OVERRUN ERROR
8F (143) -- SERIAL BUS DATA FRAME CHECKSUM ERROR
90 (144) -- DEVICE DONE ERROR
91 (145) -- BAD SCREEN MODE
92 (146) -- FUNCTION NOT SUPPORTED BY HANDLER
93 (147) -- INSUFFICIENT MEMORY FOR SCREEN MODE

A0 (160) -- DISK DRIVE # ERROR
A1 (161) -- TOO MANY OPEN DISK FILES
A2 (162) -- DISK FULL
A3 (163) -- FATAL DISK I/O ERROR
A4 (164) -- INTERNAL FILE # MISMATCH
A5 (165) -- FILE NAME ERROR
A6 (166) -- POINT DATA LENGTH ERROR
A7 (167) -- FILE LOCKED
A8 (168) -- COMMAND INVALID FOR DISK
A9 (169) -- DIRECTORY FULL (64 FILES)
AA (170) -- FILE NOT FOUND
AB (171) -- POINT INVALID

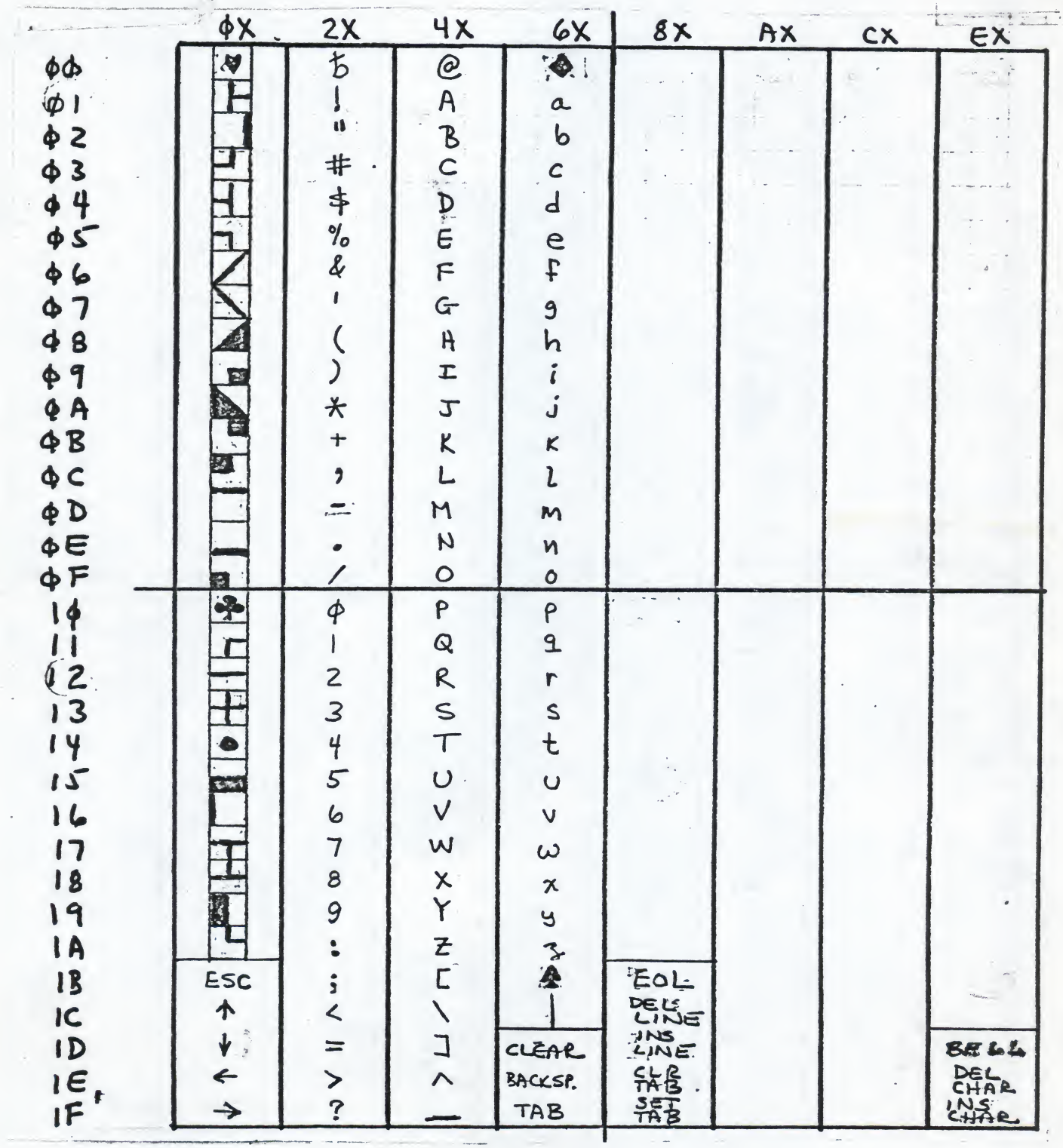
Appendix C -- SIO STATUS BYTE values.

Shown below are the known SIO STATUS BYTE values.

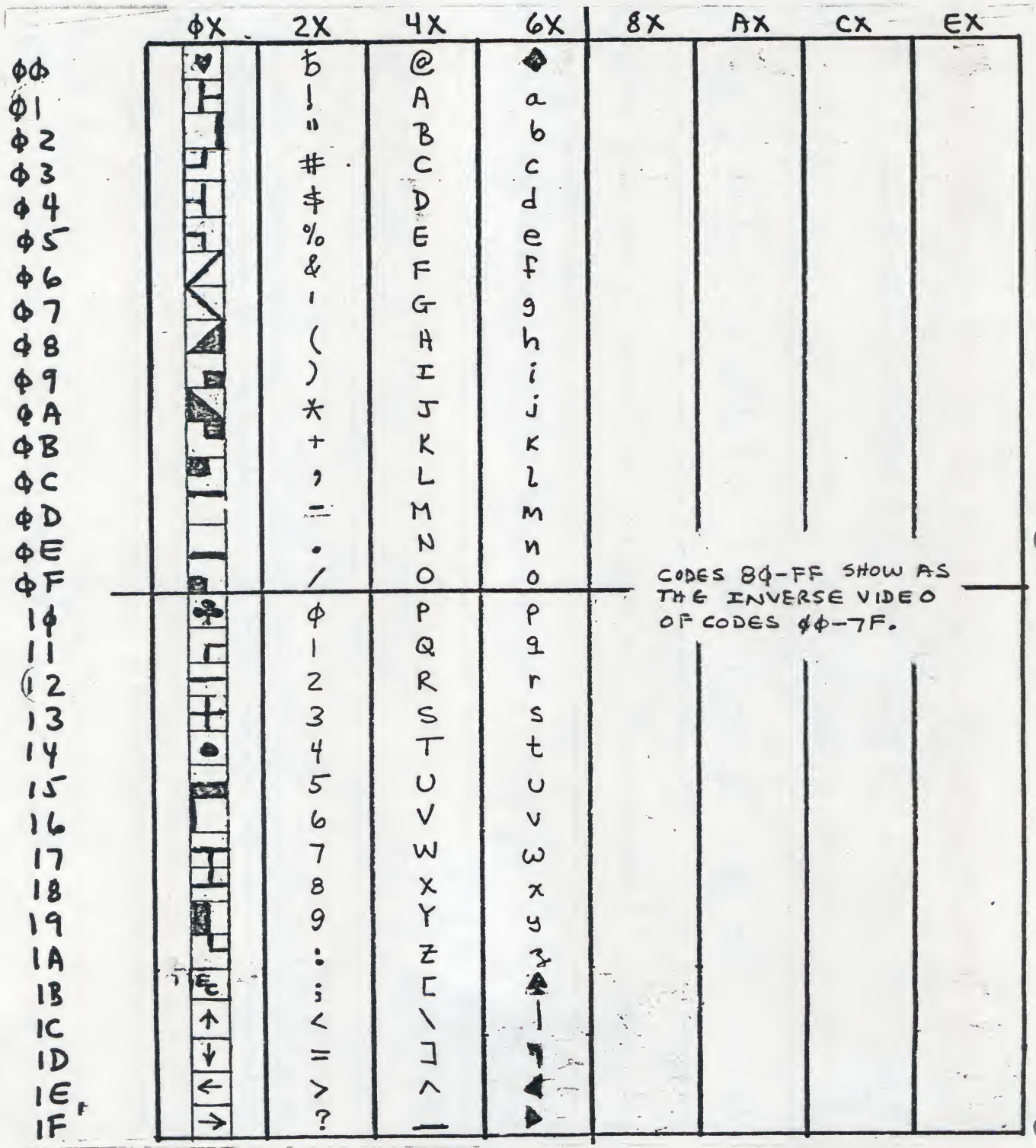
01 (001) -- OPERATION COMPLETE (NO ERRORS)

8A (138) -- DEVICE TIMEOUT (DOESN'T RESPOND)
8B (139) -- DEVICE NAK
8C (140) -- SERIAL BUS INPUT FRAMING ERROR
8E (142) -- SERIAL BUS DATA FRAME OVERRUN ERROR
8F (143) -- SERIAL BUS DATA FRAME CHECKSUM ERROR
90 (144) -- DEVICE DONE ERROR

Appendix D -- ATASCII codes



Appendix E -- Display codes (ATASCII)



Appendix F -- Keyboard codes (ATASCII)

00	,	20	<space>	40	@	60	^.	80-9A	)|(00-1A
01	A	21	!	41	A	61	a	9B	<return> & ^3
02	B	22	"	42	B	62	b	9C	s<del>
03	C	23	#	43	C	63	c	9D	s<insert>
04	D	24	$	44	D	64	d	9E	^<tab>
05	E	25	%	45	E	65	e	9F	s<tab>
06	F	26	&	46	F	66	f	A0-FC	)|(20-7C
07	G	27	'	47	G	67	g	FD	^2
08	H	28	(	48	H	68	h	FE	^<del>
09	I	29	)	49	I	69	i	FF	^<insert>
0A	J	2A	*	4A	J	6A	j		
0B	K	2B	+	4B	K	6B	k		
0C	L	2C	,	4C	L	6C	l		
0D	M	2D	-	4D	M	6D	m		
0E	N	2E	.	4E	N	6E	n		
0F	O	2F	/	4F	O	6F	o		
10	P	30	0	50	P	70	p		
11	Q	31	1	51	Q	71	q		
12	R	32	2	52	R	72	r		
13	S	33	3	53	S	73	s		
14	T	34	4	54	T	74	t		
15	U	35	5	55	U	75	u		
16	V	36	6	56	V	76	v		
17	W	37	7	57	W	77	w		
18	X	38	8	58	X	78	x		
19	Y	39	9	59	Y	79	y		
1A	Z	3A	:	5A	Z	7A	z		
1B	<esc>	3B	;	5B	[	7B	;		
1C	<up>	3C	<	5C	\	7C	|		
1D	<down>	3D	=	5D	]	7D	<clear>		
1E	<left>	3E	>	5E	^	7E	<back>		
1F	<right>	3F	?	5F	_	7F	<tab>		

<clear> ::= s< or ^<
<return> ::= <return> or s<return> or ^<return>
<esc> ::= <esc> or s<esc> or ^<esc>
<space> ::= <space> or s<space> or ^<space>

Where: s as a prefix indicates SHIFT.
^ as a prefix indicates CTRL.
)|(as a prefix indicates Atari key invert active.

Appendix G -- Printer codes (ATASCII)

Character set for "normal" mode printing:

20	<space>	40	@	60	`
21	!	41	A	61	a
22	"	42	B	62	b
23	#	43	C	63	c
24	$	44	D	64	d
25	%	45	E	65	e
26	&	46	F	66	f
27	'	47	G	67	g
28	(	48	H	68	h
29	)	49	I	69	i
2A	*	4A	J	6A	j
2B	+	4B	K	6B	k
2C	,	4C	L	6C	l
2D	-	4D	M	6D	m
2E	.	4E	N	6E	n
2F	/	4F	O	6F	o
30	0	50	P	70	p
31	1	51	Q	71	q
32	2	52	R	72	r
33	3	53	S	73	s
34	4	54	T	74	t
35	5	55	U	75	u
36	6	56	V	76	v
37	7	57	W	77	w
38	8	58	X	78	x
39	9	59	Y	79	y
3A	:	5A	Z	7A	z
3B	;	5B	[	7B	{
3C	<	5C	\	7C	|
3D	=	5D	]	7D	}
3E	>	5E		7E	~
3F	?	5F	_	7F	<space>

Note: the following codes print differently than defined by the ATASCII definition.

00 through 1F print blank.
60 prints ` instead of "diamond".
7B prints { instead of "spade".
7D prints } instead of "clear".
7E prints ~ instead of "backspace".
7F prints blank instead of "tab".

Character set for "sideways" mode printing:

		40	@	60	@
		41	A	61	A
		42	B	62	B
		43	C	63	C
		44	D	64	D
		45	E	65	E
		46	F	66	F
		47	G	67	G
		48	H	68	H
		49	I	69	I
		4A	J	6A	J
		4B	K	6B	K
		4C	L	6C	L
		4D	M	6D	M
		4E	N	6E	N
		4F	O	6F	O
30	0	50	P	70	P
31	1	51	Q	71	Q
32	2	52	R	72	R
33	3	53	S	73	S
34	4	54	T	74	T
35	5	55	U	75	U
36	6	56	V	76	V
37	7	57	W	77	W
38	8	58	X	78	X
39	9	59	Y	79	Y
3A	:	5A	Z	7A	Z
3B	;	5B	[	7B	[
3C	<	5C	\	7C	\
3D	=	5D	]	7D	]
3E	>	5E	<up>	7E	<up>
3F	?	5F	<left>	7F	<left>

Note: the following codes print differently than defined by the ATASCII definition.

00 through 2F print blank.
5E prints "up arrow" instead of ^.
5F prints "left arrow" instead of _.
60 through 7F repeats 40 through 5F instead of proper set.

Appendix H -- Screen mode characteristics

Mode #	Horiz. posit.	Vert. w/o sp	Vert. w sp	Colors	Data value	Color reg.	Memory reqd.
0	40	24	--	2	backgd.	BAK	993
					00-FF	PF 2	
					"	PF 1*	
1	20	24	20	5	backgd.	BAK	513
					00-3F	PF 0	
					40-7F	PF 1	
					80-BF	PF 2	
					C0-FF	PF 3	
2	20	12	10	5	backgd.	BAK	261
					00-3F	PF 0	
					40-7F	PF 1	
					80-BF	PF 2	
					C0-FF	PF 3	
3	40	24	20	4	0	BAK	273
					1	PF 0	
					2	PF 1	
					3	PF 2	
4	80	48	40	2	0	BAK	537
					1	PF 0	
5	80	48	40	4	0	BAK	1017
					1	PF 0	
					2	PF 1	
					3	PF 2	
6	160	96	80	2	0	BAK	2025
					1	PF 0	
7	160	96	80	4	0	BAK	3945
					1	PF 0	
					2	PF 1	
					3	PF 2	
8	320	192	160	2	0	PF 2	7900
					1	PF 1*	
9	80	192	--	1	Note 2		7900
10	80	192	--	9	0	PM 0	7900
					1	PM 1	
					2	PM 2	
					3	PM 3	
					4	PF 0	
					5	PF 1	
					6	PF 2	
					7	PF 3	
					8	BAK	
					9	BAK	

				A	BAK	
				B	BAK	
				C	PF 0	
				D	PF 1	
				E	PF 2	
				F	PF 3	
11	80	192	--	16	Note 3	7900

Notes:

* Uses color of PF 2, lum of PF 1.
2 Uses color of BAK, lum of data value ($0-F).
3 Uses color of data value ($0-F), lum of BAK.

PF x ::= Playfield color register x.
PM x ::= Player/Missile color register x.
BAK ::= Background color register (also known as PF 4).

The form of a color register byte is shown below:

```
 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+
| color | lum |0|
+-+-+-+-+-+-+-+-+
```

Where:

color (hex values)	lum
0 = gray	0 = minimum luminance
1 = light orange	1 =
2 = orange	2 =
3 = red orange	3 = (increasing
4 = pink	4 = luminance)
5 = purple	5 =
6 = purple-blue	6 =
7 = blue	7 = maximum luminance
8 = blue	
9 = light blue	
A = turquoise	
B = green-blue	
C = green	
D = yellow-green	
E = orange-green	
F = light orange	

The home position (0,0) for the text window is the upper left corner of the window.

ENABLE/INHIBIT OF CONTROL CODES IN TEXT

Normally all text mode control codes are operated upon as received, but sometimes it is desireable to have the control codes displayed as if they were data characters. This is done by setting the variable DSPFLG [02FE] to any non-zero value before outputting the data containing control codes. Setting DSPFLG to zero restores normal processing of text control codes.

Appendix I -- Serial Bus I.D. and command summary

Serial bus device I.D.s

Floppy disks	D1-D4	$31-34
Printer	P1	$40
RS-232	P2	$4F
	R1-R4	$50-53

Serial bus control codes

ACK	- $41	('A')
NAK	- $4E	('N')
COMPLETE	- $43	('C')
ERR	- $45	('E')

Serial bus command codes

READ	- $52	('R')	Disk
WRITE	- $57	('W')	Printer/Disk
STATUS	- $53	('S')	Printer/Disk
PUT	- $50	('P')	Disk
FORMAT	- $21	('!')	Disk

Appendix J -- ROM vectors

The fixed address O.S. ROM JMP vectors are shown below; at each address is a JMP instruction to the indicated routine.

Name	Addr	Reference	Function
DISKIV	E450	*	Disk handler initialization
DSKINV	E453	5.4.2	Disk handler entry.
CIOV	E456	5.2	CIO utility entry.
SIOV	E459	9.3	SIO utility entry.
SETVBV	E45C	6.7.2	Set system timers routine.
SYSVBV	E45F	6.3	Stage 1 VBLANK entry.
XITVBV	E462	6.3	Exit VBLANK entry.
SIOINV	E465	*	SIO utility initialization.
SENDEV	E468	*	Send enable routine.
INTINV	E46B	*	Interrupt handler initialization.
CIOINV	E46E	*	CIO utility initialization.
BLKBDV	E471	3.1.1	Blackboard mode entry.
WARMSV	E474	7.	Warmstart (RESET) entry.
COLDSV	E477	7.	Coldstart (power-up) entry.
RBLOKV	E47A	*	Cassette read block entry.
CSOPIV	E47D	*	Cassette OPEN input entry.

* These vectors are for O.S. internal use only.

The fixed address Floating Point Package ROM routine entry point addresses are shown below; complete descriptions of the corresponding routines are provided in section 8.

AFP	D800	ASCII to F.P. convert.
FASC	D8E6	F.P. to ASCII convert.
IFP	D9AA	Integer to F.P. convert.
FPI	D9D2	F.P. to integer convert.
FADD	DA66	F.P. add.
FSUB	DA60	F.P. subtract.
FMUL	DADB	F.P. multiply
FDIV	DB28	F.P. divide.
LOG	DECD	F.P. base e logarithm.
LOG10	DED1	F.P. base 10 logarithm.
EXP	DDC0	F.P. base e exponentiation.
EXP10	DDCC	F.P. base 10 exponentiation.
PLYEVL	DD40	F.P. polynomial evaluation.
ZFR0	DA44	Clear FR0.
ZF1	DA46	Clear F.P. number.
FLD0R	DD89	Load F.P. number.
FLD0P	DD8D	Load F.P. number.
FLD1R	DD98	Load F.P. number.
FLD1P	DD9C	Load F.P. number.
FST0R	DDA7	Store F.P. number.
FST0P	DDAB	Store F.P. number.
FMOVE	DDB6	Move F.P. number.

The base addresses of the handler vectors for the resident handlers are shown below:

Screen Editor (E)	E400
Display handler (S)	E410
Keyboard handler (K)	E420
Printer handler (P)	E430
Cassette handler (C)	E440

See section 5.4.1 for the format of the entry for each handler.

INDEX

The subject index contains three forms of references:

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Appendex, such as 'App B'
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THE TEXT FILES ARE ALL TRANSFERRED TO THE TANDEM. THE TANDEM NAMES ARE SHOWN BELOW FOLLOWED BY THE O.S. MANUAL HEADER NAME. THE TANDEM FILE ORDER IS NOT THE SAME AS THE O.S. MANUAL ORDER; THAT ORDER IS SHOWN LATER.

Harry

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F1	CIO.DESC
F2	CIO.DEV3
F3	PROG.DEV
F4	DATA.BAS07
F5	DATA.BAS19
F6	DATA.BAS27
F7	DATA.BAS37
F8	DATA.BAS45
F9	APP.ALL
F10	ALPHA.LIST
F11	NUM.LIST
F12	IOXMPL
F13	OS.INDEX
F14	ADV.TECH
F15	CIO.DEV1
F16	CIO.DEV2
F17	NEW.HAND
F18	NEW.HAND2
F19	ENVIRON
F20	INTERRUPT
F21	OSTOC
F22	CIO.DEV0
F23	FLOAT
F24	MEMORY
F25	INIT
F26	NON.CIO
F27	FUNC.ORG
F28	DEV.CHAR
F29	INTRO
F30	CONFIG
F31	SIO.BUS
F32	STANDARDS
F33	MEM.DYN

HERE ARE THE TANDEM FILE NAMES IN THE ORDER THAT THE MANUAL WAS PUT TOGETHER:

OSTOC	F21
INTRO	F29
FUNC. ORG	F27
CONFIG	F30
MEMORY	F24
DATA. BAS07	F4
DATA. BAS19	F5
DATA. BAS27	F6
DATA. BAS37	F7
DATA. BAS45	F8
ALPHA. LIST	F10
NUM. LIST	F11
MEM. DYN	F33
CIO. DESC	F1
IOXMPL	F12
CIO. DEV0	F22
CIO. DEV1	F15
CIO. DEV2	F16
CIO. DEV3	F2
NON. CIO	F26
DEV. CHAR	F28
INTERRUPT	F20
INIT	F25
FLOAT	F23
NEW. HAND	F17
SIO. BUS	F31
NEW. HAND2	F18
ENVIRON	F19
ADV. TECH	F14
STANDARDS	F32
PROG. DEV	F3
APP. ALL	F9
OS. INDEX	F13